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Serial Reactions Considered as Conditioned Reactions

BY

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FOREWORD

The author of this study is indebted to certain persons for their various helpful influences. First among these should be mentioned the several members of the Department of Psychology of The Pennsylvania State College. In addition, the author wishes to acknowledge a most valuable remote association with Professor Clark L. Hull of Yale University. These kindly advisors have contributed encouragement and critical guidance admittedly beyond objective measurement.

WILLIAM M. LEPLEY

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INTRODUCTION

The author of this monograph has two major objectives. First, he intends to present a reformulation and an elaboration of the hypothesis which appeared recently under the title: A Theory of Serial Learning and Forgetting Based Upon Conditioned Reflex Principles (19). Second, he intends to submit experimental evidence which seems to support this modified and elaborated hypothesis. The reformulation consists of the detailed exposition of the alternative interpretation suggested in the above-mentioned article (19, 283).

The two major experiments were planned for the study of remote associations under varied conditions. An attempt is made to investigate remote association as a function of the length of the forgetting interval. Further, this same phenomenon is studied as a function of the subject's degree of mastery of the learned materials. The minor experiments, concerned with serial learning order, were suggested by certain casual observations made in the course of the major experiments. Briefly, serial learning order is studied as a function of the practice of the learner, and as a function of the age of the learner.

In order to forestall, at least partially, some of the timeworn criticisms usually directed against stimulus-response formulations of psychological problems, the author wishes to declare himself with respect to the use of certain terms and other symbolic practices. First, the selection of stimulus units and reaction units is admittedly arbitrary. Second, it is not assumed that complex reactions are built by the summation of simple reactions. Third, the illustrative figures in the first chapter are not intended to be neurological diagrams. In general, the simplicity of treatment was evolved in the interest of clear exposition. The hypotheses are intentionally stated in an exact and unequivocal manner in order that they may be examined with precision. Their lack of ambiguity is a matter of the author's intention. They were intended for experimental testing and not for debate.

CHAPTER I

THE MAJOR HYPOTHESIS [1]

This theoretical development will be cast in such terms as will best harmonize with the experimental procedure to follow. We shall be dealing with serial material and we shall represent the members of these series by the conventional symbols wherever possible. Further, we shall let the stimulus symbols represent visually presented nonsense syllables. Below is given a key to the interpretation of the diagrams.

S — Visual stimulus
R — Vocal response
s — Kinaesthetic and auditory stimuli arising from R
> — Produces or gives rise to
═══> — Previously established language habits
- - - -> — Immediate excitatory tendencies
———> — Remote excitatory tendencies
- - - - -| — Inhibitory tendencies

In the learning of serial acts it is assumed:

1. That immediate associations or immediate excitatory tendencies are established having the nature of higher order, simultaneous, or near simultaneous conditioned reactions.

2. That remote excitatory tendencies, as demonstrated by Ebbinghaus (6) and by Hall (8) are established, having the dual nature of trace and delayed conditioned reactions, as demonstrated by Pavlov (27, 88–105, 39–40).

We shall elaborate these assumptions in order that they may be made precisely meaningful, and that their implications may be clearly indicated. We shall follow the hypothetical establish-

[1] This chapter contains elaborated excerpts from the author's previous article, "A Theory of Serial Learning and Forgetting Based upon Conditioned Reflex Principles," which was published in the May, 1932, issue of the *Psychological Review*. These elaborated excerpts and the five figures in this chapter are included in this writing by permission of the Psychological Review Company.

ment of tendencies or associations throughout the learning of a series of nonsense syllables barely to be learned, that is, to be learned to the point of one perfect anticipatory performance. First, we have, at the beginning of practice, a situation wherein the subject simply responds vocally to the successively presented members of the series. This situation is represented diagrammatically in Fig. 1. The visual stimuli S_1, S_2, etc., evoke respec-

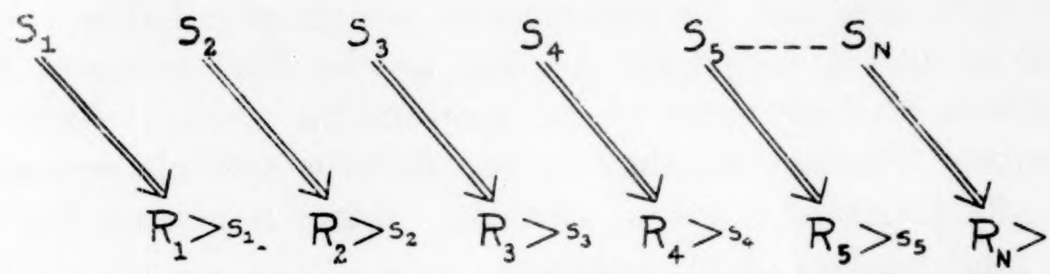

FIG. 1. Visual stimulus series, vocal response series and the auditory-kinaesthetic stimulus series arising from the vocal response series.

tively the vocal responses R_1, R_2, etc. These responses are, of course, made possible by previously established language habits.

It is to be noted that s_1 (kinaesthetic and auditory) arising from R_1, and also S_1 (visual) immediately precede $S_2 \Longrightarrow R_2$. This relationship suggests that, following the redintegrative principle, the complex $\frac{S_1}{s_1}$ may acquire the ability to evoke R_2 without S_2 being present. In other words, $\frac{S_1}{s_1}$ becomes a conditioned stimulus for response R_2 and $\frac{S_1}{s_1}$ ———$>R_2$ becomes a simultaneous or near simultaneous conditioned reaction. Likewise, $\frac{S_2}{s_2}$ and $\frac{S_3}{s_3}$ become the conditioned stimuli for R_3 and R_4 respectively, and so on throughout the series. Thus, our subject, being stimulated by S_1 and having responded R_1, may, being stimulated by s_1, auditory-kinaesthetic, respond R_2 before S_2 is presented, and so on throughout the series. Further, when these responses precede their former visual stimuli, they are reinforced by the appearance of the visual stimuli. When this becomes possible throughout one perfect anticipatory performance we shall

arbitrarily say that the subject has barely learned the series. This situation is represented in Fig. 2.[2]

Now, for the sake of a simplified diagrammatic representation, let us use but one component of each stimulus complex. S_1 has

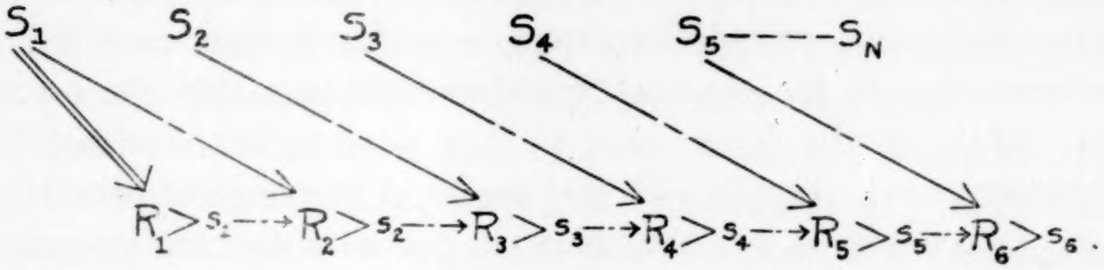

FIG. 2. Visual stimuli S_1, etc., with respective auditory-kinaesthetic stimuli s_1, etc., constitute stimulus complexes or patterns serving to evoke vocal responses R_2, etc.

acquired the ability to evoke R_2; we might quite as well use $s_1 ——— > R_2$; S_2 has acquired the ability to evoke R_3, etc.[3] This situation is represented in Fig. 3.

So far we have considered only the establishment of immediate excitatory tendencies. We have still to consider the establishment of remote excitatory tendencies. Referring to Fig. 3, Ebbinghaus (**6**) has demonstrated that S_1 tends not only to evoke

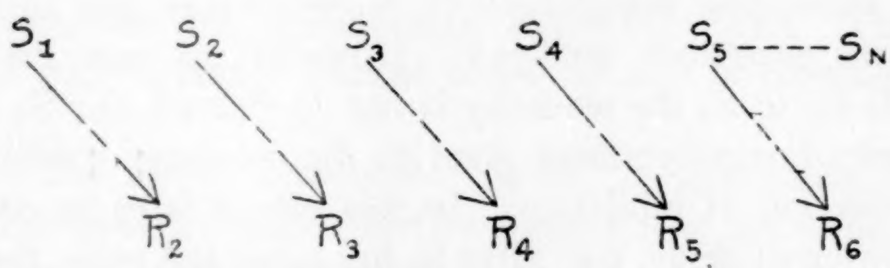

FIG. 3. Conditioned immediate excitatory tendencies.

R_2, but also tends to evoke R_3, R_4, etc., with progressively weaker excitatory tendencies. Likewise, S_2 tends also to evoke R_4, R_5, etc. These remote excitatory tendencies are added to our diagram and appear in Fig. 4, represented by single solid lines.

[2] This development of the establishment of immediate excitatory tendencies is essentially that of C. L. Hull (**9**).

[3] S_1 is considered as if presented at the beginning of each trial, so in each trial $S_1 \Longrightarrow R_1$ (R_1 being either explicit or implicit) is nothing more than an old language habit.

Now we may consider R_3, R_4, etc., as conditioned delayed reactions to S_1; in other words, conditioned to a trace effect of S_1. There is no reason to presume a fundamental difference between delayed conditioning and trace conditioning. In each case the reaction is delayed, and in each case the conditioning is due to the perseveration of stimulation, though in the former case it is a perseveration in the external world as well as within the organism, while in the latter case it is a perseveration within the organism only. Pavlov (27, 40) assumed this organic perseveration. To continue, we have here, in our situation, the necessary conditions for the establishment of excitatory and inhibitory tendencies analogous to those of the well known delayed conditioned reaction.

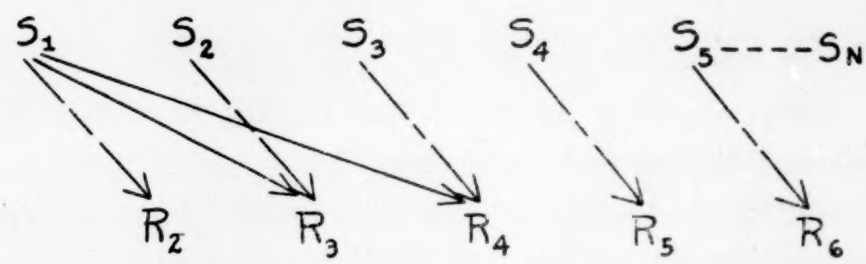

FIG. 4. Conditioned immediate and remote excitatory tendencies.

When the subject responds R_2 to S_1 the immediately succeeding appearance of S_2 reinforces this conditioned immediate excitatory tendency. However, in case the subject responds R_3 to S_1 the tendency is not reinforced, for S_2 appears. This lack of reinforcement gives us the necessary conditions for the production of inhibition. In this case it is to be considered as inhibition of delay, for, after S_2 has come and gone, the remote excitatory tendency S_1———>R_3 becomes appropriate. The response R_3 occurring just before S_3 appears is an appropriate response and is reinforced by the appearance of S_3. In other words, the remote excitatory tendency S_1———>R_3 perseveres but is held in check by an inhibitory tendency for the appropriate period of delay, after which R_3 is excited as an appropriate delayed reaction to S_1. In such a manner might we treat the increasing degrees of remoteness. Thus, as the learning of the series progresses, remote excitatory tendencies, held in check by inhibitory tendencies for appropriate periods of delay, are established.

These two types of tendency are analogous to the two phases of the delayed reaction as demonstrated by Pavlov (27, 88–105). To repeat, the establishment of the inhibitory tendencies or phases is accomplished by a lack of reinforcement occasioned by the appearance of the intervening stimulus or stimuli. The establishment of the excitatory tendencies, or phases, is accomplished by reinforcement after a period of delay or, in other words, after the intervening stimulus or stimuli have come and gone.

Now, considering the nature of a barely learned series, according to these assumptions, there are established: (1) immediate excitatory tendencies having the nature of higher order, simultaneous or near simultaneous conditioned reactions, and (2) remote excitatory tendencies, held in check for appropriate periods of delay by inhibitory tendencies, thus having the dual nature of the

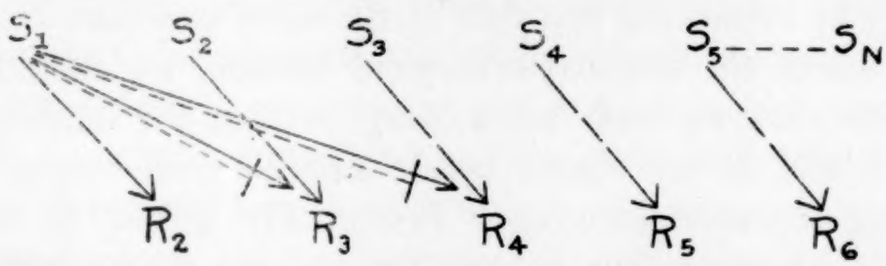

FIG. 5. Conditioned immediate and remote excitatory tendencies and conditioned inhibitory tendencies in the form of inhibition of delay.

well known delayed conditioned reaction. This 'internal' nature of such a barely learned series of acts is represented in Fig. 5.

Such is the major hypothesis. With the hypothesis formulated in this precise manner certain implications are immediately apparent, and certain deductions are made possible. As will be shown in later chapters, this simple hypothesis serves to relate certain phenomena of the conditioned reaction to certain phenomena of serial learning. Its greatest service is in the setting of new, experimentally accessible problems. It serves well as an instrument of controlled and directed, rather than blindly exploratory, research. The chapters immediately following are submitted as exemplifying exploration of this guided character.

CHAPTER II

REMOTE EXCITATION AS A FUNCTION OF THE LENGTH OF THE FORGETTING INTERVAL

I. Deductions

Having considered the learning of serial acts in the light of the foregoing hypothesis, let us now turn to a consideration of the probable behavior of these various tendencies beginning with the cessation of practice.[4] First, if we were to test for remote excitatory tendencies immediately or soon after the original learning, by relearning test lists at the same exposure interval as that at which the original lists were learned, we should not be able to demonstrate their functioning, because the inhibited delay phases would be of inappropriate lengths with respect to the relearning exposure intervals. Presumably, as will be discussed later, this demonstration would wait upon the shortening of these delay phases with a lapse of time. To explain: if the original lists are learned in a 1–2–3–4–5–6–7–8–9–10–11–12 order, and the derived test lists in a 1–3–5–7–9–11–2–4–6–8–10–12 order, and both are learned using the same exposure rhythm, then, for example, the 1–3 interval in relearning the test list is just one-half the length of the 1–3 interval in the learning of the original series. This, then, is the first deduction. *Immediately and shortly following the bare learning or slight overlearning of a series of acts one should not be able to demonstrate the functioning of remote excitatory tendencies.* Second, following a relatively longer interval of forgetting one should be able to demonstrate the functioning of remote excitatory tendencies because one would expect a progressive shortening of the periods of delay; or, in more precise terms, one would expect the creeping forward of the

[4] This monograph deals throughout with remote excitatory tendencies of the first degree. That is to say, the test series are considered as being formulated by the skipping of one stimulus unit.

delayed reactions which are held in check by inhibition of delay. It may well be that this may take the form of the creeping tendency described by Hull (10) and given, by him, much significance, especially in the case of defense reactions. Switzer (32) has recently demonstrated this tendency with the GSR.[5] To continue, when this progressive shortening of the period of delay approaches and attains to the point at which the length of delay is appropriate with respect to the relearning exposure intervals of the test lists, one should be able to demonstrate the functioning of remote excitatory tendencies. This, then, is the second deduction: *After a relatively longer interval of forgetting one should be able to demonstrate the functioning of remote excitatory tendencies.* Third, considering now the concurrent weakening of all tendencies, after a still longer period of forgetting, a test of remote excitatory tendencies should reveal their weakening. There appears to be no reason why these remote tendencies should not suffer the various obliterating influences to which immediate excitatory tendencies are subject. This, then, is the third deduction: *Following still longer intervals of forgetting one should be able to demonstrate the weakening or possibly the disappearance of remote excitatory tendencies.*

Here, then, are three clear-cut deductions based directly and logically upon the foregoing hypothesis.

II. The Experiment

(Experiment I)

a. *The objective.* The major objective of this experiment is to test for the three deductions listed above; in general terms, to study remote excitation as a function of the length of the forgetting interval.

b. *The apparatus.* The multiple exposure machine used in this and in the subsequent experiments is of the author's design and construction. The machine provides for the accurately timed, successive exposure of serial, nonsense syllable, learning material.

[5] It should be noted that the immediate excitatory tendencies also have short delays and, under certain conditions, might likewise exhibit a creeping tendency.

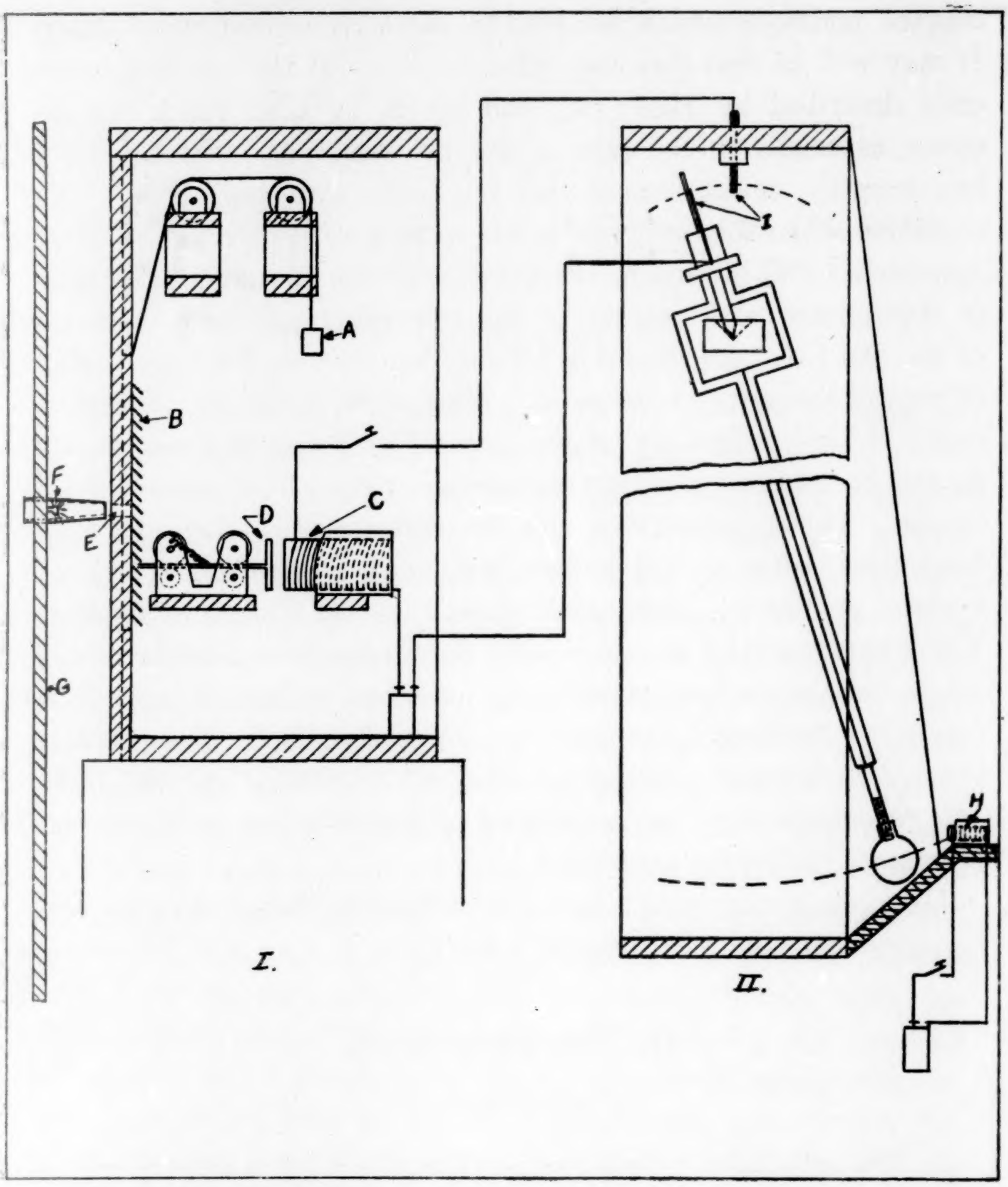

FIG. 6. Multiple exposure apparatus. (I. represents the exposure apparatus. II. represents the timing mechanism. A is a counterweight for the vertically sliding carriage, B. The carriage holds the syllable list. C is an electromagnet which activates the pawl, D, which in turn engages the steel rack on the back of the carriage. E is the exposure window. F is the exposure window light. G is a partition which separates the subject from the apparatus and the experimenter. The timing mechanism, II., is a two second pendulum which regulates the flow of current through the electromagnet, C, by means of the contacts, I. The lower contact is insulated on one side so that the mechanism makes and breaks the circuit once in the course of a double excursion. H is an electromagnetic release for the pendulum. The syllables are exposed as the carriage falls one space every two seconds.

Each syllable is exposed for two seconds. The machine with its significant adjuncts is represented in Fig. 6.

c. *The learning material.* The original lists of nonsense syllables from which the test and control lists were derived, were made up by choosing twelve syllables at random from Glaze's (7) sixteen tables. That is to say, each list contained one syllable from each of twelve of Glaze's sixteen tables. This practice was resorted to because the large number of syllables required exceeded the number in any one of Glaze's tables. Otherwise, lists more nearly equated in terms of difficulty might have been obtained by selecting from one table. This random choice was departed from only when the following rules were, by chance, violated. In such cases, a second random choice was made from the same table.

1. Each vowel, including y, appeared twice and only twice in any one list.
2. The immediate sequence of syllables containing the same vowel was avoided.
3. No initial consonant appeared more than once in a list.
4. No final consonant appeared more than once in a list.
5. Sequences wherein the final consonant of one syllable was identical with the initial consonant of the following syllable were avoided.
6. Obviously meaningful syllable sequences were excluded.

In this manner, twenty-four original lists were formulated. From each of twelve of these lists was derived a remote excitation test list. The technique of Ebbinghaus (6) was used, skipping one syllable. From each of a second group of twelve lists was derived a control list. This was accomplished by the chance permutation of the syllables. Chance permutation was departed from only when original list sequences and first order remote association sequences of syllables appeared. In such cases a second derivation was made. It should be noted here that these derived control lists contain all sorts of forward and backward associations *except immediate associations and first order remote associations.* They are not control lists in the sense that they contain no associations but only in the sense that they wholly lack

the first order, remote associations which are to be studied and which are prominent in the test lists. The constant error, which might arise from the use of such controls, is at least partially ruled out by the procedure to be described. All lists were lettered upon white cardboard strips in one-fourth inch, black India ink letters. These strips were of such width as to fit snugly into the carriage of the multiple exposure machine.

d. *The subjects.* The experimental group consisted of ten, unselected, undergraduate students, all of whom were completely naïve with respect to the experimental procedure and its implications.

e. *General procedure.* 1. All learning and relearning was by the anticipation method.

2. The criterion of mastery was held constant at one perfect anticipatory performance.

3. All comparisons of learning with relearning were made in terms of saving scores. The criterial trials were included in these comparisons.

4. The following instructions were twice read to each subject on the occasion of his first experimental performance:

The subject was seated before the lighted exposure window and the directions were read. "Do you see this little window here? You are to sit here and watch it. I am going to sit on the other side and run the machine. When I start the machine, meaningless three-letter syllables will begin to appear in the window. The first time through you are to read them aloud as they appear. When they have all come and gone, I will reset the machine and start them over again, but this time you are not to read them as they come. Instead, after the first one appears, you are to try to say the second one before it appears. Even if you are not sure, say what you think it is. If you can't say it, just wait for it to come and then, when it does come, try to say the third one before it appears, and so on throughout the list. We shall do this over and over again until you are able to go all the way through the list saying each syllable just before it comes, or in other words, when you see the syllable that comes just

before it. Do not practice the syllables while the machine is being reset. Ready?" Then the machine was started and the procedure gone through as indicated. Each time, the subject was given the "Ready?" signal two seconds before the first syllable was exposed. The exposure window light was always extinguished while the machine was being reset, and lighted again just before the "Ready?" signal. A period of eight seconds elapsed between the last exposure of one trial and the first exposure of the next. In no case was it necessary to repeat further or to modify these instructions. As the subject was dismissed at the close of the first learning period these additional instructions were given: "There is one more thing that is very important. Never practice the syllables after you have left the experimental situation."

5. The experimenter kept a complete trial-by-trial record of all responses.

6. Due to the length of some of the inter-performance periods no attempt was made to control the activity of the subject between learning and relearning performances.

7. The time of day at which performances were scheduled was allowed to vary conforming to the convenience of the subjects. The laboriousness of the technique precluded the possibility of controlling this factor.

8. Each subject learned two practice lists before beginning the true experimental program.

9. In no instance did any subject learn more than one original list and one derived list in twenty-four hours. Thus, between learning and relearning there was no interpolation of similar activities.

f. *Specific procedure.* With the practice of the learners, as a group, held constant by rotating the order of the forgetting intervals among the subjects and with possible differences in the syllable lists held constant by rotating the lists among the forgetting intervals, each subject was twice tested for remote excitation in his performance at the end of each forgetting interval. These forgetting intervals were ten minutes, thirty minutes, one hour,

three hours, six hours, and twenty-four hours. Below is the detailed program for each subject, for one forgetting interval:

First day	(a)	Learn an original list.
	(b)	Relearn the list in test form.
Second day:	(a)	Learn an original list.
	(b)	Relearn the list in control form.
Third day:	(a)	Learn an original list.
	(b)	Relearn the list in test form.
Fourth day:	(a)	Learn an original list.
	(b)	Relearn the list in control form.

This program was constant for all subjects and for all forgetting intervals except the twenty-four hour interval, where, of course, the relearning of the derived lists would take place on the days following the original learning.

The attempt to control practice effects and possible differences in the learning materials was made according to the scheme outlined below. A set of material consists of the four original lists and the derived lists used for measurement at one interval. Subject I was first tested at the ten minute interval with Set of Material No. 1. Subject II was tested first at the thirty minute interval with Set of Material No. 1. Subject VI was tested last at the six hour interval with Set of Material No. 6. As originally planned, there were twelve subjects in two groups of six. However, two subjects failed to complete the experimental program. To this extent the experiment falls short of the ideal control of practice effects and possible differences in the learning materials.

Subject	Sequence
I	10 mins. (1), 30 mins. (2), 1 hr. (3), 3 hrs. (4), 6 hrs. (5), 24 hrs. (6).
II	30 mins. (1), 1 hr. (2), 3 hrs. (3), 6 hrs. (4), 24 hrs. (5), 10 mins. (6).
III	1 hr. (1), 3 hrs. (2), 6 hrs. (3), 24 hrs. (4), 10 mins. (5), 30 mins. (6).
IV	3 hrs. (1), 6 hrs. (2), 24 hrs. (3), 10 mins. (4), 30 mins. (5), 1 hr. (6).
V	6 hrs. (1), 24 hrs. (2), 10 mins. (3), 30 mins. (4), 1 hr. (5), 3 hrs. (6).
VI	24 hrs. (1), 10 mins. (2), 30 mins. (3), 1 hr. (4), 3 hrs. (5), 6 hrs. (6).

III. Explanation of Tables and Figures [6]

The data summarily presented in Table I were gathered according to the procedure outlined above. From these data the graphs in Fig. 7 were plotted. Each point on these graphs represents the mean of twenty measures. Each point represents the mean relearning advantage of test lists over control lists at the end of the particular forgetting interval. Measurement was accomplished in terms of saving scores. Consider the graph based upon error score measurements. The two graphs are in essential agreement. Therefore, we shall consider only one of them in detail. This graph, as a whole, may be considered as representing the functional strength of remote excitation as a function of the length of the forgetting interval.

TABLE I [7]

Remote Excitation as a Function of the Length of the Forgetting Interval. N = 10

		Mean Per cent Saved Upon Relearning				Mean Diff. (Test minus Control)		
		Test Series		Control Series				
Forgetting Interval	Type of Score	Mean Per cent	Standard Error of the Mean	Mean Per cent	Standard Error of the Mean	Mean Diff.	Standard Error of the Mean Diff.	Critical Ratio
10 mins.	Trials	—0.5	5.94	6.3	9.18	—6.8	11.59	0.59
	Errors	1.3	5.45	10.3	8.87	—9.0	9.25	0.97
30 mins.	Trials	—7.6	9.15	—38.3	14.91	30.7	16.05	1.91
	Errors	—8.1	7.68	—54.2	15.32	46.1	15.26	3.02
1 hr.	Trials	—8.8	12.09	—12.8	5.48	4.0	14.52	0.28
	Errors	—15.2	12.71	—19.6	11.92	4.4	21.13	0.21
3 hrs.	Trials	—11.1	4.98	—7.3	6.06	—3.8	8.89	0.43
	Errors	—17.0	6.32	—4.4	6.82	—12.6	10.35	1.22
6 hrs.	Trials	—7.2	9.05	—3.0	6.93	—4.2	9.03	0.47
	Errors	—8.4	9.02	—9.4	8.08	1.0	10.12	0.10
24 hrs.	Trials	—4.8	10.08	—0.2	8.81	—4.6	11.05	0.42
	Errors	—4.0	13.98	3.2	7.09	—7.2	17.16	0.42

IV. Results and Interpretations

Referring to this graph and to the values in Table I from which it was plotted, note:

1. At the end of the ten minute interval there is a small

[6] The summary tables appearing in this article were constructed from complete tables contained in the Appendix of a thesis which is on file in the Library of The Pennsylvania State College.

[7] The negative values in the Mean Diff. Column indicate obtained relearning advantages in favor of control lists.

obtained advantage in favor of the control lists. The value is —9.0. Using the standard error of the difference technique and taking into account the correlation element, the critical ratio is but 0.97.[8] Thus, the first deduction is confirmed. Remote excitation is not demonstrated to be functional after a relatively short interval of forgetting. Interpreted in the light of the hypothesis upon which this deduction was based, this result is

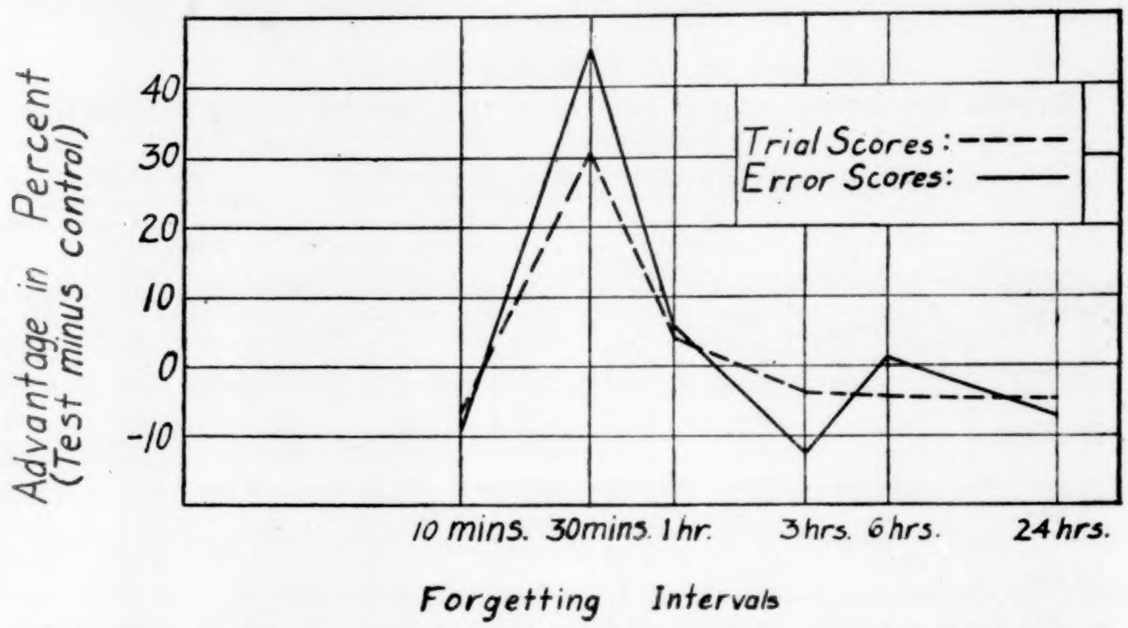

FIG. 7. Remote excitation as a function of the length of the forgetting interval. The negative values of this graph represent obtained relearning advantages in favor of control lists. The abscissa scale in this graph and in the similar graphs to follow is logarithmic in nature.

construed as indicating that the progressive shortening of the inhibited delay phases of the first order remote excitatory tendencies has not attained to such a point that they are appropriate with respect to the relearning exposure rhythm of the test lists.

2. At the end of the thirty minute interval there is a 46.1 point advantage in favor of the test lists. Using the same statistical

[8] The statistical technique used does not involve the computation of correlation coefficients. Mean saving scores for each subject in test lists and control lists were computed. The mean, control-list, saving score for each subject was then subtracted algebraically from his mean, test-list, saving score. The Standard Error of the Mean Difference, then, is simply the Standard Error of the Mean of the Series of differences so obtained. This technique is used throughout the study in all cases wherein the Means of possibly correlated series are compared. In all other cases involving the Comparison of Means, the conventional formula, $\sigma_{Diff.} = \sqrt{\sigma^2_{M_1} + \sigma^2_{M_2}}$, is used.

technique, the critical ratio is found to be 3.02. Thus, there is a reliable confirmation of the second deduction. Remote excitation is demonstrated to be functional after a relatively longer interval of forgetting. Interpreted in the light of the hypothesis, the thirty minute interval seems to be of sufficient length to allow the progressive shortening of the inhibited delay phases of the remote excitatory tendencies to a point whereat the latent periods are appropriate with respect to the relearning rhythm.

3. From this thirty minute point on, the advantage of test lists over control lists fluctuates between positive and negative values, but at no point investigated does there occur a reliable difference. Necessarily abstaining from a detailed interpretation of this portion of the graph, the third deduction is confirmed. Remote excitation is not demonstrated to be functional after a still longer interval of forgetting. This may be interpreted as resulting from the weakening or obliviscence of the remote excitatory tendencies. It should be noted here that failure to demonstrate does not insure the total absence of function. However, the point of maximum function is rather clearly indicated to be at the end of the thirty minute interval.

Obviously the foregoing interpretations have been cast intentionally and somewhat gratuitously in terms of the hypothesis under investigation. They remain in need of qualification. For the most part, this qualifying interpretation is left to a later chapter. However, at this point we shall consider these data in comparison with the data from previous studies of remote excitation. First among these studies should be mentioned that of Ebbinghaus (6). Ebbinghaus used a constant learning and relearning rhythm. He tested for remote excitation after a relatively long interval of forgetting, after twenty-four hours, with positive results. There is no evidence for remote excitation at the end of the twenty-four hour interval in the present data. There is no evidence for remote excitation at any point tested beyond the thirty minute point. This apparent abrupt disappearance of remote excitation is probably misleading. As before stated, the failure to demonstrate does not prove the absence of remote excitation. It may well be that the technique used is not

sufficiently sensitive. The most remarkable discrepancy between the present data and the data of Ebbinghaus consists of the lack of substantial saving in the relearning of test lists at all points. With comparable derived lists, Ebbinghaus reports a mean saving of 10.8 per cent at the end of twenty-four hours. We should have no evidence for remote excitation at all if it were not for the relatively greater interference in the control lists at the thirty minute point. The author is at a loss to explain this discrepancy. It is necessary to conclude that the results of the present study are not in harmony with the results of Ebbinghaus.

A recent study by Hall (8) offers still greater difficulties. Miss Hall, in an attempt to reconcile the results of Ebbinghaus and Cason (3), so planned her experiment that the latent period for first order remote excitatory tendencies in her test lists remained exactly the same as for the same tendencies in the original lists. Instead of simply skipping one syllable and thereby shortening the period by one-half, as did Ebbinghaus and the present author, she interpolated syllables from other lists, thus maintaining the original latent periods. According to our hypothesis, such a technique should permit the demonstration of remote excitatory tendencies immediately following the original learning. Somewhat contrary to this, she found but slight evidence for remote excitation when she tested immediately. Using the same technique and testing for remote excitation after a forgetting period of one week, she found reliable evidence for remote excitation. This latter finding is harmonious with the results of Ebbinghaus but thus, again, inharmonious with the results of the present study. Here again we find the fundamental discrepancy noted before. Hall's results show a substantial saving in the relearning of test lists, which the results of the present study do not. The saving scores for Hall's subjects averaged 32.2 per cent for the immediate relearning of test lists and 27.1 per cent for the relearning of test lists after one week. Apparently, the potent factors at work in the present study are factors of interference of some sort and the only evidence of remote excitation we have results from a lesser degree of interference in the test lists at the end of the thirty minute forgetting interval.

The graph in Fig. 7 might quite as well be labeled in terms of relative interference or relative associative inhibition.

V. Summary

The data here reported may be interpreted in terms of the hypothesis under consideration. First, remote excitation is not demonstrated to be functional after a relatively brief interval of forgetting. Second, remote excitation is demonstrated to be functional after a relatively longer interval of forgetting. Third, remote excitation is not demonstrated to be functional after a still longer interval of forgetting. In general, with the criterion of mastery held constant, remote excitation, as measured, appears to be a function of the length of the forgetting interval. This fluctuation in measured function may be interpreted as resulting from the decreasing latency of and the obliviscence of remote excitatory tendencies having the nature of delayed conditioned reactions.

Necessary qualifications of the above interpretation are apparent and the author is by no means assured that the effective factors have been identified. Further, the results of this study are considerably out of harmony with the results of previous studies.

CHAPTER III

REMOTE EXCITATION AS A FUNCTION OF THE DEGREE OF LEARNING

I. Deductions

There is an obvious corollary to the general conclusion of Chapter II. If it is true that the facilitative effect of remote excitatory tendencies is a function of the interval between the learning of the original and derived lists, when the derived lists involve a shortening of the delay in the S–R sequence, then, assuming that the rate of the shortening of the delay in the remote excitatory tendencies is a function of their fixity at the conclusion of the original learning, the facilitative effect of remote excitatory tendencies in our particular experimental situation should be a function of the degree of learning of the original lists.

To elaborate, let us begin again with the assumptions of the major hypothesis. In a learned series of acts it is assumed: first, that there are established immediate excitatory tendencies having the nature of higher order, simultaneous conditioned reactions; and second, that there are established remote forward excitatory tendencies having the nature of higher order trace or delayed conditioned reactions. The details of this establishment and of the 'inner nature' of such a series will not be repeated here. A third assumption is to be made here, that the strength or stability of all tendencies is increased by continued learning or overlearning. This assumption is not unfounded. With respect to immediate associations and to simultaneous or near simultaneous conditioned reactions, it is a commonplace. With respect to trace or delayed conditioned reactions, both Pavlov (27, 89) and Switzer (32) have shown that the period of delay, thus the inhibitory tendency, is stabilized by continued conditioning; and also that the reaction, thus the excitatory tendency, is by such

means more thoroughly established. Hence, if our second assumption be sound, it logically follows that the progressive shortening of the inhibited phases of remote excitatory tendencies should be retarded by the overlearning of serial acts. In other words, it follows that the progressive shortening of the latent periods of remote excitatory tendencies should be delayed by greater degrees of learning. To express this line of thought in terms of Experiment I, assuming that the observed maximum facilitative effect at thirty minutes represents the true maximum, if the original lists had been more thoroughly learned we should have observed a decrease in the measured function of remote excitatory tendencies at the end of the thirty minute forgetting interval. Because, according to these assumptions, we would have retarded the decrease in the latent periods of the remote excitatory tendencies, so that at thirty minutes they would have been still inappropriate with respect to the relearning rhythm of the test lists. Under such conditions the point of maximum measured function should occur later in the course of forgetting, at the end of a longer forgetting interval. This, then, is the deduction which the experiment submitted in this chapter was designed to test: *If the observed maximum function at thirty minutes is the true maximum, then, holding the forgetting interval constant at thirty minutes and varying the degree of learning we should be able to show that the greater degree of learning results in a decrease in the measurable function of remote excitatory tendencies.*

II. The Experiment

(Experiment II)

a. *The objective.* The objective of this experiment is to test for the deduction expressed above; in general terms, to study remote excitation as a function of the degree of learning.

b. *The apparatus.* The same apparatus was used as in the preceding experiment.

c. *The learning material.* The original and derived lists used in this experiment were taken from among those used in the pre-

ceding experiment. In all, there were sixteen original lists, eight of these derived in test form and eight derived in control form.

d. *The subjects.* This experimental group consisted of twenty unselected undergraduate students, all of whom were completely naïve with respect to the experimental procedure and its implications.

e. *General procedure.* 1. All learning and relearning was by the anticipation method.

2. The forgetting interval between the learning of original lists and the relearning of the lists in test or control form was held constant at thirty minutes.

3. The degree of learning was varied by requiring the subjects to learn and relearn one-half of the materials to one perfect anticipatory performance and the other half to six perfect performances. The use of these criteria resulted in mean, original learning, trial scores of 9.58 repetitions and 16.59 repetitions, respectively.

4. All comparisons of learning with relearning were made in terms of saving scores. In these comparisons only the first criterial trials were included.

5. The same instructions were given to this experimental group as were given to the group in the preceding experiment except that the subjects of this group were warned that sometimes they would have to achieve but one perfect anticipatory performance, while at other times they would have to achieve six perfect performances.

6. Again the subjects were warned not to practice the syllables after they had left the experimental situation. No other attempt was made to control the activity of the subject between learning and relearning performances.

7. The time of day at which performances were scheduled was allowed to vary according to the convenience of the subject.

8. Each subject learned two practice lists before beginning the true experimental program.

9. In no instance did any subject learn more than one original list and one derived list in twenty-four hours.

f. *Specific procedure.* 1. With the interval of forgetting held constant, each subject was tested eight times for remote excita-

tion in his performance at the end of a thirty minute forgetting interval. For four of these tests the criterion of mastery was held constant at one perfect anticipatory performance. We shall speak of this as the first degree of learning. For the remaining four of these tests the criterion of mastery was held constant at six perfect anticipatory performances. We shall speak of this as the second degree of learning.

2. In order to control the influence of possible differences in the syllable lists, the learning materials were systematically alternated between use with measurement involving the first degree of learning and use with measurement involving the second degree of learning. Thus, any syllable list was used one-half of the time with first degree learning and the other half of the time with second degree learning. The details of this alternation are presented later.

In order to control the possible influence of practice effects, four different experimental programs were followed. The first day of each of these programs is outlined below.

Program (a)

Day's program (1)

Learn an original list to the first degree.

After a thirty minute forgetting interval, relearn the list to the first degree in control form.

Program (b)

Day's program (2)

Learn an original list to the first degree.

After a thirty minute forgetting interval, relearn the list to the first degree in test form.

Program (c)

Day's program (3)

Learn an original list to the second degree.

After a thirty minute forgetting interval, relearn the list to the second degree in control form.[9]

[9] The second degree relearning was carried to six perfect performances in order that the instructions might be kept constant.

Program (d)

Day's program (4)

Learn an original list to the second degree.

After a thirty minute forgetting interval, relearn the list to the second degree in test form.

Following the first day, there was a systematic alternation of test and control measurements and of first and second degree measurements in each of the four programs. There were twenty subjects in all; five subjects followed each of the four programs. Thus, five subjects began Program (a) with Day's program (1), which was followed by Days' programs (2), (3), and (4), in that sequence. Five subjects began Program (b) with Day's program (2), which was followed by Days' programs (3), (4), and (1). Five subjects began Program (c) with Day's program (3), which was followed by Days' programs (4), (1), and (2). The remaining five subjects began Program (d) with Day's program (4), which was followed by Days' programs (1), (2), and (3). Each subject repeated his program cycle four times.

In order to control possible differences in the materials, the sequence of materials was held constant. To explain, test list No. I, with its original, was always used first in all programs. Thus, it was used one-half of the time in first degree measurements and the other half in second degree measurements. Likewise, control list No. I was always used first in all programs. Thus, it was used one-half of the time in first degree measurements and one-half of the time in second degree measurements.

The other test lists from No. II to No. VIII followed in invariable sequence. The same was true for the eight control lists. Therefore as before stated, each list, with its original was used one-half of the time with the one degree of learning and one-half of the time with the other degree of learning.

III. Explanation of Tables and Figures

The data summarily presented in Table II were gathered according to the procedure outlined above.

TABLE II[10]

Remote Excitation as a Function of the Degree of Learning, with the Forgetting Interval Held Constant at Thirty Minutes. N = 20

Degree of Learning	Type of Score	Type of Series	Mean Per cent Saved upon Relearning	Standard Error of the Mean	Mean Diff. (Test Minus Control)	Standard Error of the Mean Diff.	Critical Ratio
First	Trials	Test	—4.4	3.80			
		Control	—16.7	6.24	12.3	6.65	1.85
	Errors	Test	—3.8	4.82			
		Control	—28.3	7.25	24.5	7.20	3.40
Second	Trials	Test	—3.8	5.10			
		Control	—3.5	5.16	—0.3	6.48	0.05
	Errors	Test	—9.3	6.10			
		Control	—6.8	5.93	—2.5	7.04	0.36

Based upon the data in Table II, the column graph designated as Fig. 8 was constructed. The height value of each column represents the mean of eighty measures. Each value represents the mean relearning advantage of test lists over control lists for the degree of learning indicated. Measurement was accomplished in terms of saving scores. As before stated, only the first criterial trial was included in the computation of saving scores.

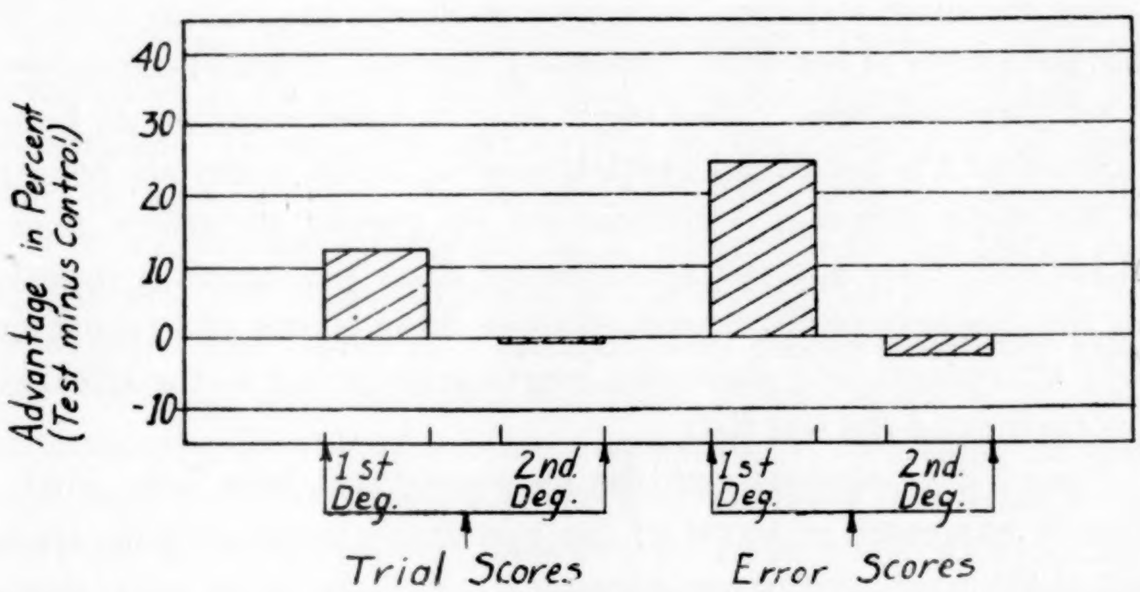

Fig. 8. Remote excitation as a function of the degree of learning. Negative difference values indicate obtained relearning advantages in favor of control lists.

[10] Negative difference values indicate obtained relearning advantages in favor of control lists.

Program (d)

Day's program (4)

Learn an original list to the second degree.

After a thirty minute forgetting interval, relearn the list to the second degree in test form.

Following the first day, there was a systematic alternation of test and control measurements and of first and second degree measurements in each of the four programs. There were twenty subjects in all; five subjects followed each of the four programs. Thus, five subjects began Program (a) with Day's program (1), which was followed by Days' programs (2), (3), and (4), in that sequence. Five subjects began Program (b) with Day's program (2), which was followed by Days' programs (3), (4), and (1). Five subjects began Program (c) with Day's program (3), which was followed by Days' programs (4), (1), and (2). The remaining five subjects began Program (d) with Day's program (4), which was followed by Days' programs (1), (2), and (3). Each subject repeated his program cycle four times.

In order to control possible differences in the materials, the sequence of materials was held constant. To explain, test list No. I, with its original, was always used first in all programs. Thus, it was used one-half of the time in first degree measurements and the other half in second degree measurements. Likewise, control list No. I was always used first in all programs. Thus, it was used one-half of the time in first degree measurements and one-half of the time in second degree measurements. The other test lists from No. II to No. VIII followed in invariable sequence. The same was true for the eight control lists. Therefore as before stated, each list, with its original was used one-half of the time with the one degree of learning and one-half of the time with the other degree of learning.

III. Explanation of Tables and Figures

The data summarily presented in Table II were gathered according to the procedure outlined above.

TABLE II[10]

REMOTE EXCITATION AS A FUNCTION OF THE DEGREE OF LEARNING, WITH THE FORGETTING INTERVAL HELD CONSTANT AT THIRTY MINUTES. N = 20

Degree of Learning	Type of Score	Type of Series	Mean Per cent Saved upon Relearning	Standard Error of the Mean	Mean Diff. (Test Minus Control)	Standard Error of the Mean Diff.	Critical Ratio
First	Trials	Test	—4.4	3.80			
		Control	—16.7	6.24	12.3	6.65	1.85
	Errors	Test	—3.8	4.82			
		Control	—28.3	7.25	24.5	7.20	3.40
Second	Trials	Test	—3.8	5.10			
		Control	—3.5	5.16	—0.3	6.48	0.05
	Errors	Test	—9.3	6.10			
		Control	—6.8	5.93	—2.5	7.04	0.36

Based upon the data in Table II, the column graph designated as Fig. 8 was constructed. The height value of each column represents the mean of eighty measures. Each value represents the mean relearning advantage of test lists over control lists for the degree of learning indicated. Measurement was accomplished in terms of saving scores. As before stated, only the first criterial trial was included in the computation of saving scores.

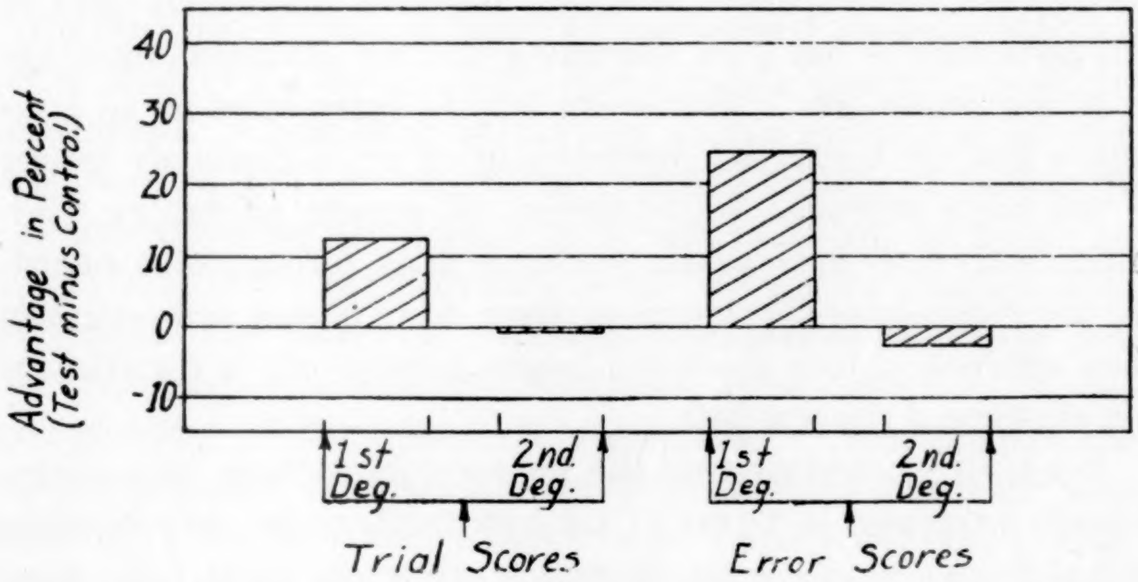

FIG. 8. Remote excitation as a function of the degree of learning. Negative difference values indicate obtained relearning advantages in favor of control lists.

[10] Negative difference values indicate obtained relearning advantages in favor of control lists.

IV. Results and Interpretations

Consider the pair of columns in Fig. 8 based upon error score measurement. The trial score measurements are in essential agreement with the error score measurements. Therefore, we shall consider only the latter in detail. Referring to this graph and to the values in Table II from which it was constructed, note:

1. The first degree measurements confirm the second deduction and the second conclusion of Chapter II. With a moderate degree of learning, remote excitation is demonstrated to be functional at the end of a thirty minute forgetting interval. There is a 24.5 point relearning advantage in favor of the test lists. Using the standard error of the difference technique and taking into account the correlation element, the critical ratio of this advantage is 3.40. Thus the confirmation is highly reliable.

2. The second degree measurements yield results in confirmation of the deduction which this experiment was designed to test. With a greater degree of learning, the length of the forgetting interval being held constant, there results a decrease in the measurable function of remote excitatory tendencies. There is a 2.5 point relearning advantage in favor of the control lists. Using the same statistical technique as above, the critical ratio of this advantage is but 0.36, indicating that the obtained advantage is an unreliable one. This result may be interpreted as an indication that the continued overlearning of serial materials results in the more thorough establishment of remote excitatory tendencies with their appropriate inhibited delay phases; thus retarding the progressive shortening of these delay phases and retarding their attainment to a shortened length appropriate to the relearning rhythm of the test lists.

Again, it is obvious that the interpretations have been intentionally expressed in terms of the hypothesis under consideration and that qualifications are necessary. For the most part, these qualifications are left to the following chapter, but here it is pertinent to compare these data with the results of previous studies. Again, the saving scores of the present study are notably inconsistent with the saving scores of Ebbinghaus (6) and of

Hall (8), and the phenomenon of interference or associative inhibition is prominent. The present data offer no evidence of saving in the relearning of either test or control lists. Again, the only advantage of test lists over control lists is in terms of less interference in the relearning of the former.

It is relevant to mention here the results of certain other studies which may be interpreted according to the present hypothesis. It has been suggested by Hall (8) that one of the factors contributing to the negative results of Cason (3) might be the considerable overlearning of the original learning materials. If we might assume that Cason's subjects used a constant relearning rhythm, then, according to our major hypothesis, we might attribute his negative results, in part, to the thorough establishment of the latent periods of the remote excitatory tendencies. This, according to our logic, would prohibit their progressive shortening to a length appropriate to the relearning rhythm of the test materials in the relatively short interval of forgetting allowed. It will be remembered that Cason, using prose materials, tested for remote associations immediately or almost immediately following the cessation of practice in the learning of the original materials.

Ebbinghaus (6) has submitted experimental evidence relevant to the effect of the degree of learning upon the strength of remote associations. Comparing the saving in the relearning of first order derived lists with the saving in the relearning of unchanged lists by expressing the former as a percentage of the latter, he reports that this value decreases as the number of repetitions of the original lists increases. He interprets this as indicating that the continued repetition is relatively more effective in the strengthening of the immediate associations. According to the hypothesis under consideration, we may interpret this result as a decrease in the measurable function of remote excitatory tendencies due to the more thorough establishment of their delay phases, thus to a retardation of the progressive shortening of their latent periods, thus to an increasing inappropriateness of the latent periods with respect to the test relearning rhythm at the time of testing. Ebbinghaus tested after a forgetting interval of

twenty-four hours. In this manner, we may interpret the results of Ebbinghaus.

Lumley (20) has made an interesting contribution to this line of thought. Using a typewriter maze, he has shown that, in the course of learning, anticipatory errors first increase and then, further along in the course of learning, decrease. For example, dividing the whole course of learning into four parts and considering anticipatory errors of all degrees, Lumley reports the following: In the first section of the learning process, 41.6 per cent of the total errors in the section were anticipatory errors. In the second section the value increased to 70.3 per cent. In the third section the value further increased to 77.1 per cent. In the last section the value decreased to 71.9 per cent. These observations have been confirmed in further experiments by Lumley (21, 22) and also by Mitchell (24), whose subjects memorized three-place numbers. Lumley (20) suggests that his results support the conclusion of Ebbinghaus that, as the degree of learning increases, in the course of learning, there are disproportionate effects in the strengthening of immediate and remote associations. In the light of our major hypothesis, the following interpretation may be suggested. If we consider remote excitatory tendencies as a source (not necessarily the only source) of anticipatory errors in learning, the initial increase reported by Lumley and Mitchell may be construed as resulting from the functioning of remote excitatory tendencies in the initial stages of establishment, during which their latent periods, or their inhibited delay phases are relatively unstable. Further, the final decrease in anticipatory errors may be interpreted as indicating the increasing stability of the remote excitatory tendencies with their inhibited delay phases of appropriate lengths.

V. Summary

The results of Experiment II appear to support the results of Experiment I in that remote excitation, as measured by this technique, is again demonstrated to be functional at the end of a thirty minute forgetting interval, the original lists having been learned to a comparable degree of mastery.

The experimental support of the hypothesis here examined is augmented by the confirmation of a fourth deduction. A greater degree of learning results in a lesser mensurability, by this technique, of remote excitation. In accordance with the major hypothesis, this may be interpreted to mean that the overlearning of serial acts results in the stabilization of the remote excitatory tendencies having the nature of delayed conditioned reactions.

If we adhere to this suggested interpretation, remote excitation in serial learning, as measured by this technique, appears to be a function of the degree of learning. In view of the notable discrepancy between the results of this study and the results of previous studies, with respect to the obtained saving scores, this interpretation is not to be urged. Here, as in Experiment I, the dominant factor operating in the relearning of test and control lists appears to be inhibitory in nature and has not been identified.

CHAPTER IV

ASSOCIATIVE INHIBITION

I. Introduction

To the careful reader an examination of the tables in the two preceding chapters will have revealed a necessity for further interpretations. The reference is to the previously mentioned marked discrepancy between the results of the experiments reported here and the results of Ebbinghaus (6) and Hall (8) as regards saving scores obtained by comparing the learning of original lists with the relearning of the lists in derived form. In order to avoid unnecessary confusion these interpretations have been reserved for the most part for treatment in the present chapter. Due to the fact that the major hypothesis, as stated, does not take into account all of the factors effective in the phenomena to be considered here, we shall depart from the form of the preceding chapters. We shall be concerned with phenomena variously referred to by the terms associative inhibition. habit interference and negative transfer.

II. Related Studies

The first experimental demonstrations of associative inhibition were contributed by Mueller and Pilzecker (25) and Mueller and Schumann (26). These early investigators formulated the law of associative inhibition somewhat as follows: if x is associated with y, then it is more difficult to associate x with z than it would have been had not the x–y association preceded. These and later studies, involving various types of learning materials, various techniques and both human and sub-human subjects, have demonstrated that associative inhibition is a complex rather than a simple phenomenon. Hunter (15) and, more recently Siipola and Israel (30) have presented summaries of this literature. Of

especial interest to us here are the studies of Bergström (1, 2) and the study made by Kline (17). Using a card sorting technique, Bergström (1) demonstrated that associative inhibitory effects may be negated by practice effects, the resultant being little or no measurable effect. In another experiment, Bergström (2) showed that the resultant associative inhibitory effect decreased as a function of the length of the interval between the first learning and the second learning. If one is guided by the original statement of the law of associative inhibition and considers the factor of obliviscence, this result seems reasonable. That is, if associative inhibitory effects are dependent upon the previous establishment of conflicting habits, the obliviscence of these habits should result in a decrease in the associative inhibitory effects. This has become a commonly accepted principle.

Now let us consider the more recent study made by Kline (17). Using meaningful materials, Kline has demonstrated that the degree of associative inhibition is a function of the degree of learning. Precisely, he has shown: First, that weakly established previous habits have little inhibitory effect upon the establishment of new habits; second, that the inhibitory effect increases with the more thorough establishment of the previous habits; but third, that beyond a certain maximum, the inhibitory effect decreases with the more thorough establishment of the previous habits. This elaborated law of associative inhibition, having been confirmed by other investigators, has become commonly accepted. Insofar as the present author is aware, an obvious corollary to this elaborated law has never been made explicit. If this elaboration be sound the generalization of Bergström (2) that the inhibitory effect decreases as a function of the length of the forgetting interval would hold only for slight and intermediate degrees of learning. If this elaboration be sound, then in the third case noted above, wherein the original establishment is very strong, one would expect, in the course of obliviscence of the previously established habits, an initial *increase* in associative inhibition followed later by a decrease. In other words, when a *very strongly* established habit which, according to Kline, gives

rise to *little* associative inhibition, becomes, in the course of obliviscence, a *moderately* established habit which, according to Kline, gives rise to greater associative inhibition, one would expect an *increase* in associative inhibition. Further along in the course of obliviscence, when the habit passes below the condition described as *moderately* established toward the *weakly* established condition which, again according to Kline, results in *little* associative inhibition, one would expect a decrease in associative inhibition. This rather striking, deducible phenomenon is apparent in the data discussed below.

This same phenomenon appears to be present in the data of Siipola and Israel (30). At least their data may be so interpreted. These experimenters, using alphabet code materials, have shown that, with the greater degrees of original learning, the interference in the learning of the second task is delayed until relatively later stages in the second learning. In their experiments, the later stages in the second learning took place after considerable forgetting intervals. Thus, the greater interference may be due to factors arising from the obliviscence of the original habit rather than to the stage of learning of the second habit. More likely the obtained resultant effects are causally related to both conditions.

III. Explanation of Tables and Figures

a. *Associative inhibition as a function of the length of the forgetting interval.* The graphs presented in Figs. 9 and 10 were plotted from the values previously noted in Table I and rearranged in Table III. Fig. 9 was plotted from trial score values and Fig. 10 from error score values. Each point represents the mean per cent saved or lost upon relearning derived test or control lists at the end of the indicated forgetting interval. Each point represents the mean of twenty measurements. Each graph, as a whole, represents resultant values, dependent upon both inhibitory and facilitative factors, varying as a function of the length of the forgetting interval.

TABLE III

ASSOCIATIVE INHIBITION AS A FUNCTION OF THE LENGTH OF THE FORGETTING INTERVAL. N = 10

		Forgetting Intervals					
		10 mins.	30 mins.	1 hr.	3 hrs.	6 hrs.	24 hrs.
Type of Series	Type of Score	Per cent Saved upon Relearning	Per cent Saved upon Relearning	Per cent Saved upon Relearning	Per cent Saved upon Relearning	Per cent Saved upon Relearning	Per cent Saved upon Relearning
Test	Trials	—0.5	—7.6	—8.8	—11.1	—7.2	—4.8
	Errors	1.3	—8.1	—15.2	—17.0	—8.4	—4.0
Control	Trials	6.3	—38.3	—12.8	—7.3	—3.0	—0.2
	Errors	10.3	—54.2	—19.6	—4.4	—9.4	3.2

b. *Associative inhibition as a function of the degree of learning.* The column graph in Fig. 11 was constructed from the values previously noted in Table II and rearranged in Table IV. The height value of each column is based upon the mean of eighty measurements. The height value of each column represents the per cent saved or lost upon relearning test or control lists, the period of forgetting being held constant at thirty minutes and the degree of original learning being varied. As before stated, this variation was from learning to one perfect anticipatory performance, in the one case, to learning to six perfect anticipatory

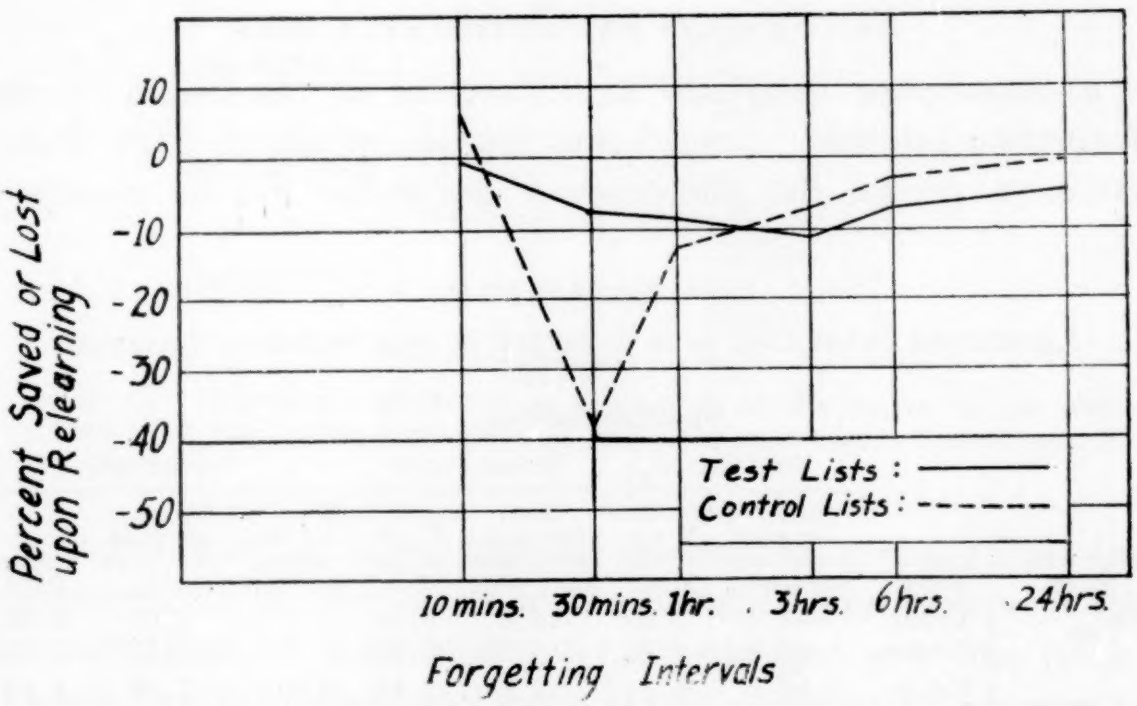

FIG. 9. Associative inhibition as a function of the length of the forgetting interval (based upon trial score measurements).

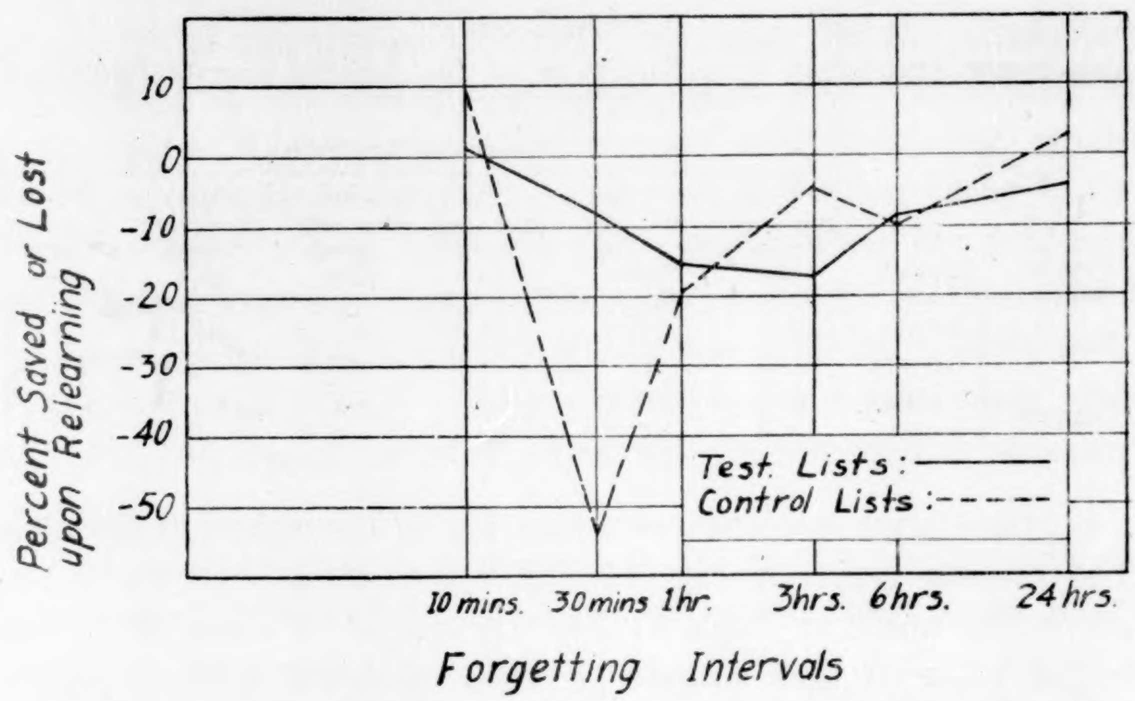

FIG. 10. Associative inhibition as a function of the length of the forgetting interval (based upon error score measurements).

performances in the second case. As a whole, Fig. 11 represents resultant values, presumably dependent upon both inhibitory and facilitative factors, varying as a function of the degree of original learning.

IV. RESULTS AND INTERPRETATIONS

a. *Associative inhibition as a function of the length of the forgetting interval.* Considering first the graphs in Figs. 9 and 10 as a group, the phenomenon demanded by the corollary

TABLE IV[11]

ASSOCIATIVE INHIBITION AS A FUNCTION OF THE DEGREE OF LEARNING.
N = 20

		Degree of Learning						
		First Degree		Second Degree		Comparison		
Type of Series	Type of Score	Mean Per cent Saved upon Relearning	Standard Error of the Mean	Mean Per cent Saved upon Relearning	Standard Error of the Mean	Mean Diff. (1st Deg. minus 2nd Deg.)	Standard Error of the Mean Diff.	Critical Ratio
Test	Trials	—4.4	3.80	—3.8	5.10	—0.6	5.89	0.10
	Errors	—3.8	4.82	—9.3	6.10	5.5	7.77	0.71
Control	Trials	—16.7	6.24	—3.5	5.16	—13.2	7.60	1.74
	Errors	—28.3	7.25	—6.8	5.93	—21.5	8.36	2.57

[11] Negative values in the difference column indicate a decrease in associative inhibition with the increase in the degree of learning.

expressed in section II of this chapter and possibly present in the data of Siipola and Israel (30) is apparent. These graphs consistently exhibit an initial increase in associative inhibition and, later in the course of obliviscence, a decrease. Interpreted in the light of the corollary, it appears that we are dealing with a degree

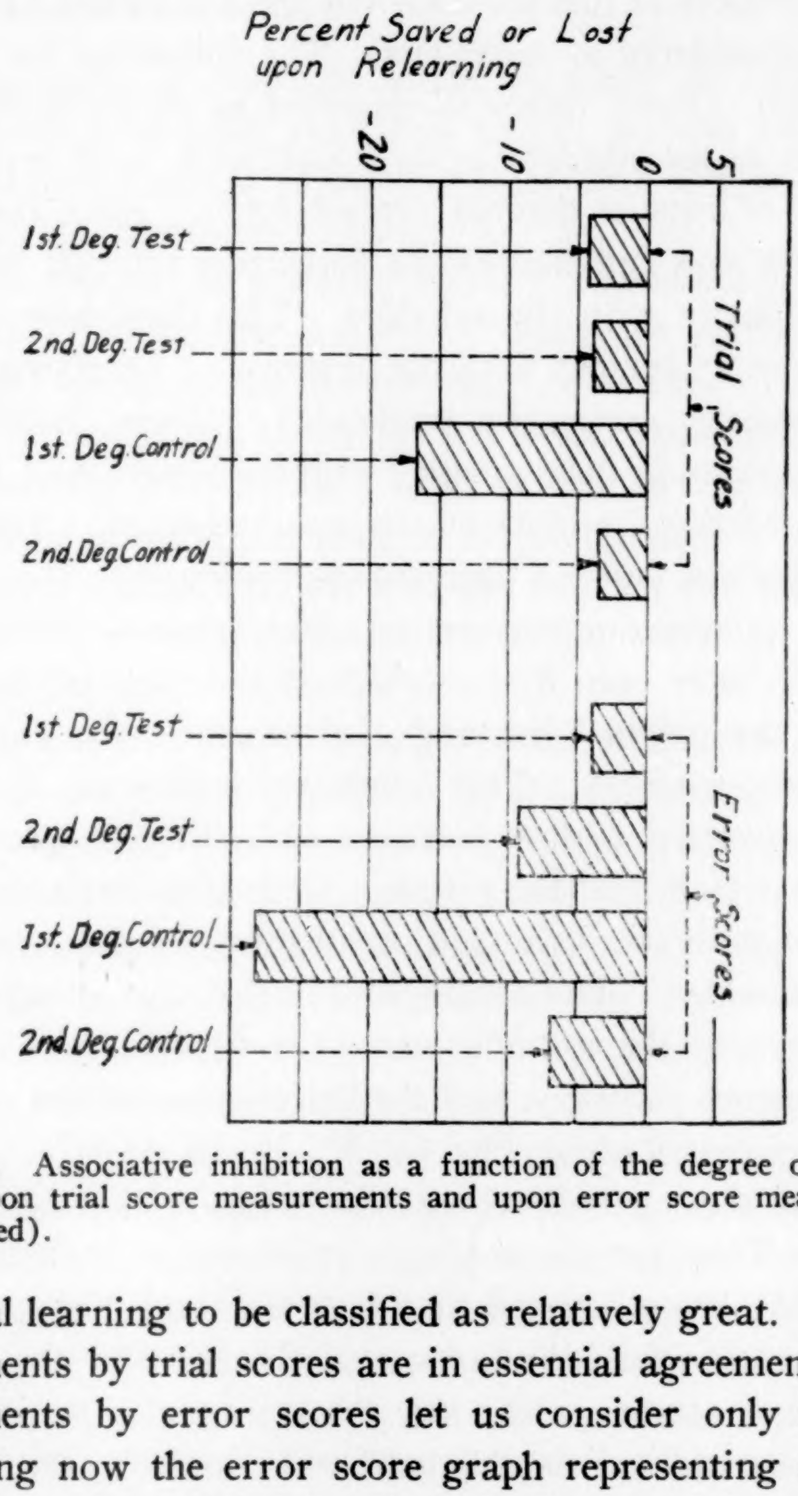

FIG. 11. Associative inhibition as a function of the degree of learning (based upon trial score measurements and upon error score measurements as indicated).

of original learning to be classified as relatively great. Since the measurements by trial scores are in essential agreement with the measurements by error scores let us consider only the latter. Considering now the error score graph representing associative inhibition in the relearning of derived control lists, note the marked increase in this function between ten minutes and thirty

minutes and, following this increase, the consistent decrease. The magnitude of the increase is from a plus 10.3 value to a minus 54.2 value. The magnitude of the decrease from the thirty minute point to the twenty-four hour point is from the minus 54.2 value to a plus 3.2 value. There are doubtless several factors operative in this phenomenon and the values, as measured, are to be considered as resultants. The following list of factors is suggested. Each factor is classified as to its probable influence, either as an inhibitor or as a facilitator, with respect to the relearning of lists in derived control form. Also, the direction of variation as a function of the forgetting interval is indicated.

1. Familiarity with the syllables. This facilitator will suffer a decrease in its potency with the progress of forgetting.

2. Immediate excitatory tendencies. These inhibitors will suffer a decrease in their potency with the progress of forgetting.

3. All orders of remote excitatory tendencies. These inhibitors will likewise suffer a decrease in potency.

4. The spontaneous recovery of other types of irrelevant reactions which have been first established and then inhibited in the course of the original learning; for example, the correction of faulty pronunciations. This inhibitory influence, if it exists, might be expected to first increase with the obliviscence of the inhibitions which hold the reaction tendencies in check, and then to decrease with the continued obliviscence of the reaction tendencies themselves. The assumption is that this complex process is analogous to the establishment, the experimental extinction, the spontaneous recovery, and the obliviscence of the conditioned reaction, as described by Pavlov (**27**, 16–32, 48–67).

In addition, there may be other factors less predictable as to their function. This list is not submitted as an exhaustive one. Hall (**8**, 73) has suggested that factors 2 and 3 above give rise to some sort of inhibition because of the fact that the old immediate and, in some cases, the remote bonds, having become inappropriate in the derived lists, must be broken. Hull (**14**) has recently expressed this thought in terms of a " frustration hypothesis ". To quote from Hull:

> "The term frustration is used here to indicate any situation in which an acquired excitatory tendency . . . is for any reason prevented from evoking its accustomed reaction. The hypothesis is that, under such circumstances, internal inhibitions will be developed which will manifest substantially the same characteristics as result from the experimental extinction of conditioned reactions."

If this hypothesis of Hull's be sound we might do well to eliminate the term associative inhibition except in such cases as the present one wherein it is probable that several factors contribute to the resultant interference effect.

Lack of experimental evidence makes it impossible to give these factors significant relative weights. Therefore, the author confines himself to suggesting that the temporal course of associative inhibition, as indicated by the graph under consideration, is a complex function, the resultant effect of the factors listed. The author wishes to point out that, if factor number 4 is a reality, and a strongly influential one, it might account for the observed fluctuation of associative inhibition from slight to relatively greater, and then to relatively less.

Let us turn now to a consideration of the error score line-graph representing associative inhibition in the relearning of derived test lists. Note the general similarity of this graph to that concerned with control lists. In this graph there is a consistent increase in associative inhibition from a plus 1.3 value at the ten minute point to a minus 17.0 value at the three hour point. Beyond the three hour point, there is a consistent decrease in associative inhibition to a minus 4.0 value at the twenty-four hour point. Note especially the difference between the two graphs at the thirty minute point. Referring back to Table I, note that the only statistically significant difference between test list values and control list values is this difference found at the thirty minute point. Subtracting the control list value from the test list value, the magnitude of the difference was found to be a plus 46.1. The ratio of this difference to its standard error was found to be 3.02. In Chapter II, we have already interpreted this difference as an index of the measurable potency of first

order, remote excitatory tendencies. Our interpretation of the test list graph is no different from our interpretation of the control list graph except for this one factor. In the relearning of derived test lists the decreasing latency of first order, remote excitatory tendencies contributes an added facilitating influence which, in the temporal course of forgetting, first increases to a maximum with the obliviscence of the inhibitory delay phases and which, beyond this maximum, decreases with the continued obliviscence of the excitatory phases. The lesser degree of associative inhibition in the relearning of test lists at the thirty minute point, as compared with associative inhibition in the relearning of control lists at the same point, is attributed to this facilitating factor which, according to the major hypothesis, is not present in the control lists.

b. *Associative inhibition as a function of the degree of learning.* Here we shall be concerned with an interpretation of the values of Table IV and Fig. 11 consistent with the major hypothesis and with our interpretation of the data in the immediately preceding section.

Let us consider first the variation in associative inhibition in the relearning of derived control lists. It is evident that the greater degree of learning (second degree) results in a decrease in associative inhibition. Measured by trial scores, this difference has a value of 13.2. The standard error of this difference is 7.60 and the critical ratio is 1.74. This decrease is a reasonably significant one. The error score measurements are in essential agreement with the trial score measurements, and the decrease is considerably more reliable. The decrease value is 21.5 and the critical ratio between this mean decrease value and its standard error is 2.57. Measured by trial scores, there is little evidence of associative inhibition in the relearning of control lists with the second degree of learning. The obtained value is a minus 3.5. Measured by error scores, there is again slight evidence of associative inhibition under these conditions. Here the obtained value is a minus 6.8. This result appears to support Kline's (17) conclusion that extremely well established habits result in little or no measurable associative inhibition.

Evidently, by raising the learning criterion from one perfect anticipatory performance to six perfect anticipatory performances, we have proceeded from a well established habit to a still more thoroughly established habit. It should be noted here that, according to the corollary demanding an initial increase in associative inhibition with the progress of the obliviscence of strongly established habits, one would here again expect such an increase with a period of forgetting somewhat longer than thirty minutes.

For a detailed interpretation of the experimental outcome noted above, let us refer again to the four factors listed in the immediately preceding section.

1. Familiarity with the syllables. This facilitator will increase in potency with a greater degree of learning.

2. Immediate excitatory tendencies. These inhibitors will increase in potency with a greater degree of overlearning.

3. All orders of remote excitatory tendencies. These inhibitors will likewise increase in potency.

4. The spontaneous recovery of other types of irrelevant reactions. This spontaneous recovery, inhibitory in its influence, will be retarded with a greater degree of learning. The greater degree of learning presumably results in their more thorough extinction. It is even conceivable that this extinction might attain to such a degree that spontaneous recovery would never occur.

Since bases upon which to weight these suggested factors are lacking, the only possible interpretation of the observed decrease in associative inhibition as a function of increased degree of learning is a general one. The increased overlearning of derived control lists accomplishes a readjustment of the relative potencies of facilitating and inhibiting influences such that there results little or no measurable associative inhibition.

Let us now turn to the values in Table IV which represent associative inhibition in the relearning of derived test lists as a function of the degree of learning. Measured by trial scores, there is no significant difference between the value obtained with the first degree of learning and the value obtained with the second degree of learning. There is an obtained decrease value

of minus 0.6, but the ratio of this difference to its standard error is only 0.10. Measured by error scores, there is an obtained increase value of plus 5.5, but the critical ratio here is only 0.71. It is legitimate to conclude that these data show no significant change in the resultant associative inhibition in the relearning of derived test lists with an increase in the degree of learning. In accordance with the major hypothesis and with preceding interpretations, this outcome may be interpreted as follows: In the greater overlearning of test lists there is a decrease in the potency of the facilitating influence arising from first order remote excitatory tendencies. This decrease in potency is attributed to the more thorough establishment of the delay phases of these remote excitatory tendencies. This more thorough establishment prohibits their progressive shortening to a length appropriate to the relearning rhythm of the test lists in the limited, thirty minute forgetting interval allowed. Consistent with our interpretation of the control list values, the decrease in the potency of this facilitating factor negates the resultant value which gave us a decrease in associative inhibition with the greater overlearning of control lists. Combining the above interpretations into one expression, the observed discrepancy between (1) the significant reduction in associative inhibition in the relearning of control lists more thoroughly overlearned and (2) no significant reduction in associative inhibition in the relearning of test lists more thoroughly overlearned, may be interpreted as being due to the varying influence of first order, remote excitatory tendencies, having the nature of delayed conditioned reactions.

V. Summary

The data from Experiments I and II have been reconsidered in an attempt to throw light upon the phenomena of associative inhibition.

On the basis of the data from Experiment I there is suggested a new ' law ' of associative inhibition. *When there is a relatively great overlearning of a series of acts, the associative inhibitory effect of such a series upon the learning of the same or similar acts in a disturbed serial order, may first increase and then decrease as a function of the length of the forgetting interval.*

At present it is impossible to predict whether or not this corollary will hold for all types of learning materials and practices. Very likely it will not. However, if we accept the foregoing interpretations, serial nature and the consequent presence of remote excitatory tendencies do not appear to be fundamentally essential conditions.

The data from the relearning of control lists in Experiment II confirm the findings of other experimenters that, in cases of thoroughly established habits, associative inhibition decreases as a function of increasingly thorough establishment.

The conclusions from Chapters II and III are reiterated in the consideration of remote excitation as a factor in associative inhibition. This factor is classified as an associative *inhibitor* in the relearning of derived control lists. In contrast with this, the influence of first order remote excitations is considered as an associative *facilitator* in the relearning of derived test lists. It is suggested that other factors are effective in the phenomena of associative inhibition and associative facilitation. These other factors are:

1. Familiarity with the syllables, a facilitator.
2. Immediate excitatory tendencies, considered as inhibitors.
3. The spontaneous recovery of irrelevant reactions which have been first established and later extinguished in the course of learning. This factor, if it exists, is considered as being inhibitory in its influence.

In agreement with other writers, it is concluded that the phenomenon of associative inhibition, as observed and measured, is the resultant effect of several influential factors, rather than a simple function.

Here it is necessary to say that these interpretations, though consistent, are somewhat gratuitous and that there is no satisfactory assurance that the effective factors have been identified.

The above reconsideration of the data from Experiments I and II fails to provide any explanation of the discrepancy between these data and the data of Ebbinghaus (6) and Hall (8) as regards the magnitude of saving scores. The need for further investigation is apparent.

CHAPTER V

SERIAL LEARNING ORDER AS A FUNCTION OF PRACTICE

I. Introduction

Experiment III, reported in this chapter, was suggested by the casual observation that, as the subjects used in Experiments I and II proceeded through their experimental programs, they appeared to be learning more and more extensively from the anterior end of the series. Or, in terms of serial learning order, the primacy effect appeared to be more pronounced later in the subject's experience with the experimental technique than earlier.

II. The Experiment

(Experiment III)

Actually, Experiment III does not represent a new experimental procedure. Certain data taken from Experiments I and II are reconsidered in an attempt to discover whether or not serial learning order varies as a function of the learner's practice.

III. Explanation of Tables and Figures

Table V and Fig. 12 represent a summary treatment of data taken from the first twelve original-series, learning records of the thirty subjects used in Experiments I and II. They represent a comparison of the composite learning order for the first six series learned and the learning order for the second six. It should be remembered that each original series learned was learned subsequently in a derived form, so the practice of these learners was approximately twice as extensive as that represented by these twelve original lists. Each serial position point in Fig. 12 is based upon a mean error score computed from one hundred and eighty learning records. Each graph, as a whole, represents the serial

TABLE V

Serial Learning Order as a Function of Practice. Composite Learning Order is Expressed in Terms of the Mean Number of Errors at Each Serial Position. N = 30 (Adult Subjects)

	Serial Position												Comparison				
Series	1	2	3	4	5	6	7	8	9	10	11	Mean Total	Mean Per cent of the Total Errors in the Anterior Half of the Series	Standard Error of the Mean	Mean Diff. (1st Six minus 2nd Six)	Standard Error of the Mean Diff.	Critical Ratio
First six learned	3.9	6.6	9.1	11.4	13.5	13.9	14.3	13.9	11.6	7.5	4.4	110.1	45.5	1.33			
Second six learned	1.6	2.4	3.5	4.9	6.3	6.5	7.0	7.0	6.6	4.9	2.9	53.6	39.4	1.48	6.1	1.17	5.21

TABLE VI

Serial Learning Order as a Function of Practice. A Comparison Based upon the Percentage of Errors Made in the Anterior Halves of the Series. N = 30 (Adult Subjects)

Series	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Mean Percent of Error in the Anterior Halves of the Series	48.8	45.5	45.5	46.3	46.6	40.5	38.3	41.8	40.6	36.8	41.2	38.0
Means by Groups of Three		46.6			44.5			40.2			38.7	

learning order for the first six series learned or the second six series learned, as indicated.

Table VI and Fig. 13 are intended to demonstrate that the changing order of learning, as a function of the practice of the learner, is continuous. In Table VI, the per cent of error in the anterior half of the series is shown for each of the twelve stages of practice. The irregular, solid line in Fig. 13 is plotted from these values. The abscissa scale represents the stages of practice. The smoothed, broken line represents simple means, combining three stages of practice.

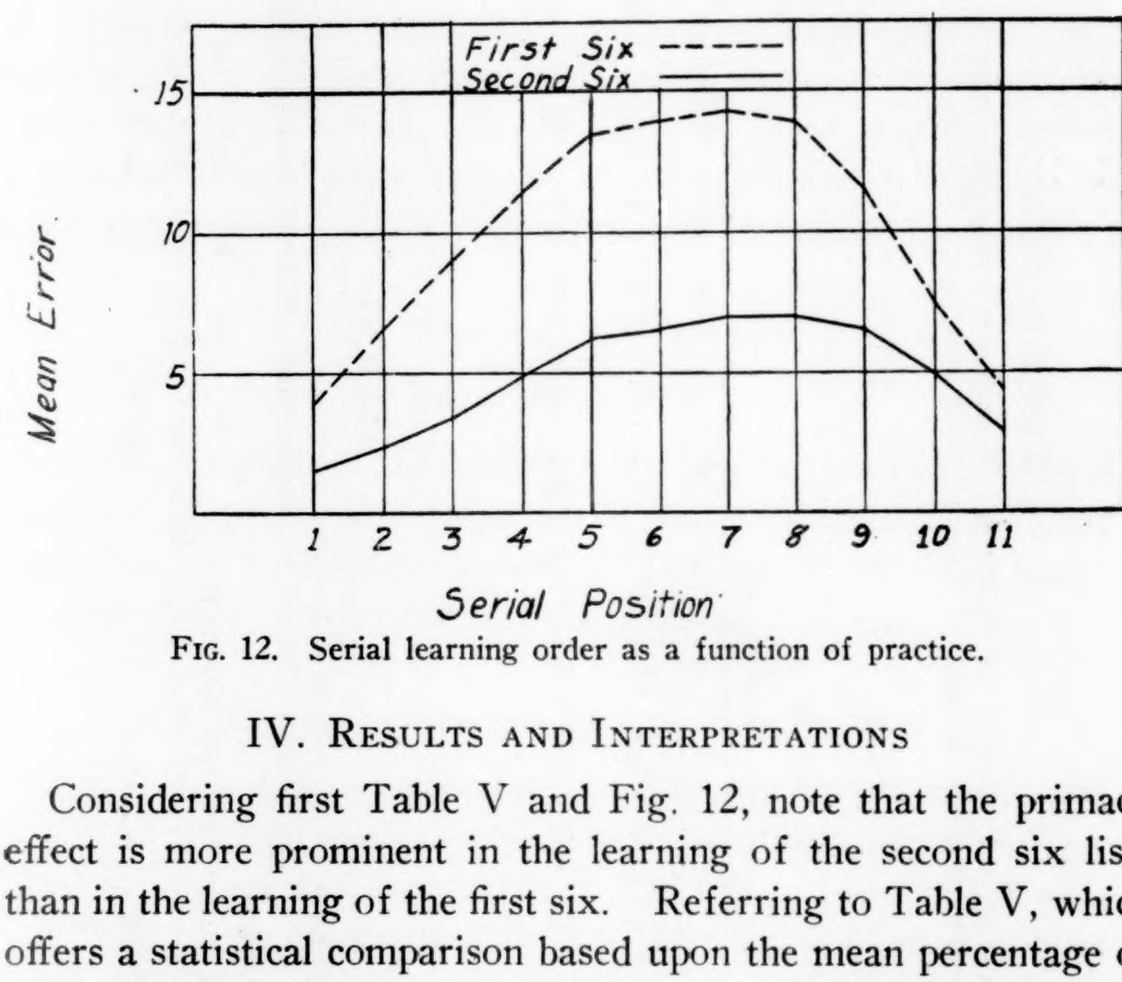

FIG. 12. Serial learning order as a function of practice.

IV. Results and Interpretations

Considering first Table V and Fig. 12, note that the primacy effect is more prominent in the learning of the second six lists than in the learning of the first six. Referring to Table V, which offers a statistical comparison based upon the mean percentage of error in the anterior halves of the series, note that this group of thirty subjects made 45.5 per cent of their errors in the anterior halves of the first six series learned. Compared with this value, note that they made only 39.4 per cent of their errors in the anterior halves of the second six series learned. The critical ratio of this 6.1 per cent difference to its standard error of 1.17 is 5.21. This difference is a highly reliable one, and it seems conclusive that

adult subjects do learn more and more extensively from the anterior end of the series with the extension of practice.

An inspection of Table VI and Fig. 13 reveals that the change in learning order noted in our gross comparison of the first six series learned with the second six learned is a continuous process. The mean per cent of error in the anterior half of the series

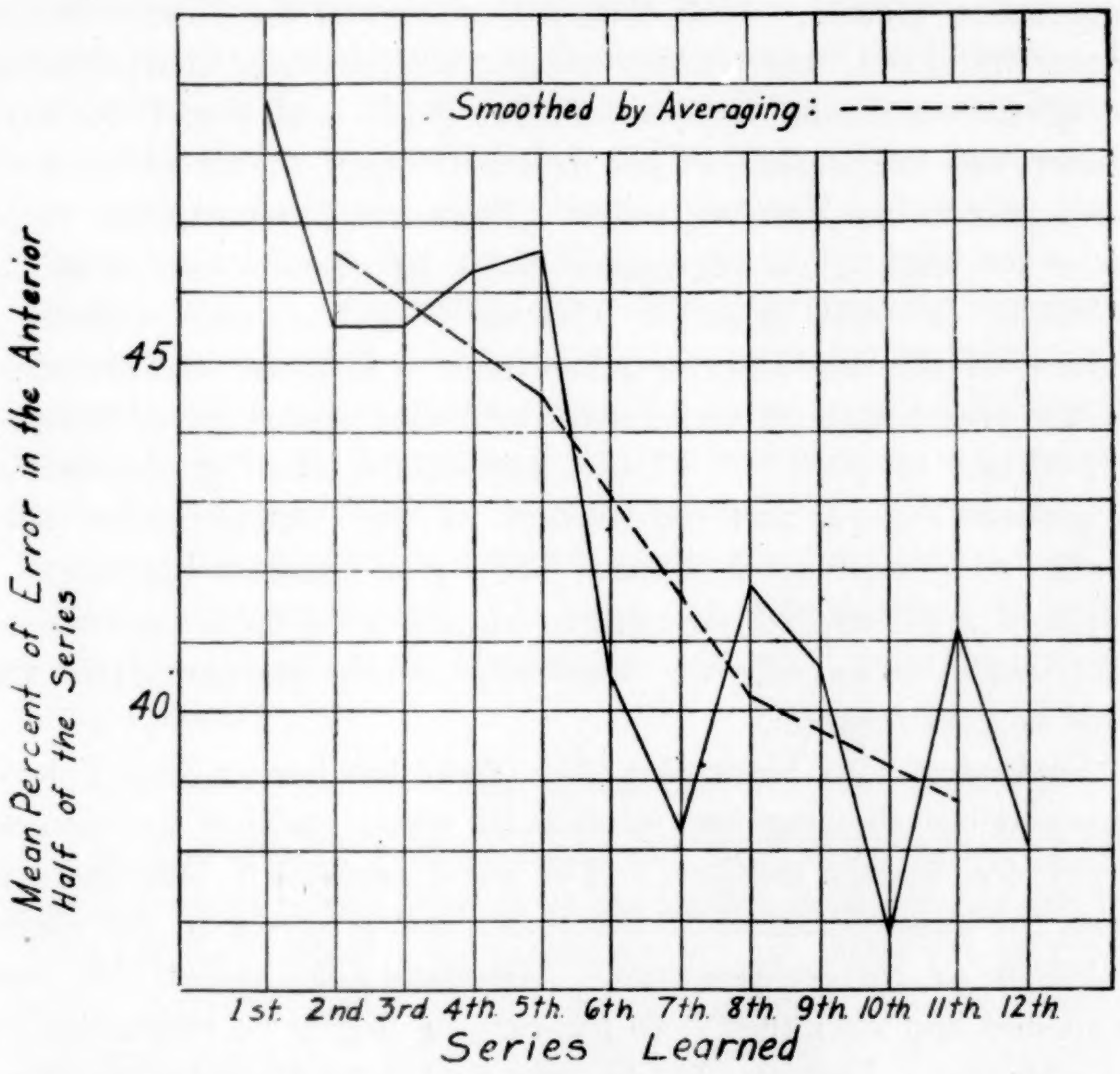

FIG. 13. Demonstrating the continuous nature of the change in learning order as a function of the practice of the learner.

varied from 46.6 in the first quarter of the practice represented to 38.7 in the last quarter or in the learning of the fourth group of three lists.

Several possible interpretations of this phenomenon of changing learning order suggest themselves. It may be that the 'memory span' of the subject increases with practice, thus allow-

ing him to learn the syllables in larger and larger groups. With such an interpretation it would be necessary to assume that this is most effective in learning the anterior half.

Various hypotheses have been put forward in the interpretation of serial learning order and various factors have been shown to be influential. Considering first, maze learning by the rat, Peterson (28) and Dashiell (4) have pointed out the influence of orientation factors. Hull, with his concept of the "habit-family hierarchy"(11), has recently offered a systematic interpretation of these orientation factors. DeCamp (5) and Kuo (18) have shown the importance of the relative length of the blind alley with respect to learning order. Most rat maze studies show some evidence of a regressive order of elimination, thus the influence of serial position. Spence (31) has lately offered a review of this literature and has made a brilliant interpretation of the phenomena of serial learning order, using the systematic hypotheses of Hull (11, 12, 13), particularly the "goal gradient hypothesis" (13), and the concept of the "habit-family hierarchy"(11) mentioned above. The "goal gradient hypothesis" assumes a differential strength of conditioning in a sequence of acts which varies with the remoteness of the segment from the final or goal reaction.

Beginning with Meumann (23), there has been a long line of experiments showing the relation of serial position to learning order for human subjects. The most consistent outcome has been the demonstration of the centripetal progress in the establishment of correct reactions. Meumann (23) noted this phenomenon and attributed it to the varying degree of concentration of attention. Lumley (20) believes that it results from grouping practices of the subjects. Welch and Burnett (33) noted a marked reduction in the primacy effect when they gave their subjects specific instructions not to rehearse the earlier syllables of a series while the later ones were being presented. They obtained an order of learning quite like the regressive order of the rat. Robinson and Brown (29) reasonably doubt the effectiveness of this sort of instruction. Further, they point out that the results of Welch and Burnett may well be a function of the manner in

which the records were taken. In their own experiments they used the anticipation method and required their subjects to spell the syllables, intending to control the attention of the learner. Speaking of the primacy effect, they conclude, "We do not believe that this is due to the rehearsal of the first few syllables during the presentation of the later ones."

Whatever the factors are, there are evidently several of them. The results of the present study demand the existence of a factor which may reasonably vary with the practice of the learner. The author wishes to suggest that this variable factor may be some sort of symbolic supplementation on the part of the subject, probably embracing grouping practices, rehearsal, and verbal associations, both logical and arbitrary. This suggestion needs to be supplemented by two assumptions: first, that this supplementation increases as a function of practice; and second, that this increase is most effective in the learning of the anterior half of the series. It should be noted here that the first assumption is contradictory to an observation reported by Meumann (23). He reports that, with continued practice, subjects make less and less use of this sort of supplementation. The brief protocols taken in the present study reveal nothing significant for the solution of this contradiction.

V. Summary

The data treated in this chapter exhibit a phenomenon of serial learning order which, insofar as the author is aware, has not been reported heretofore. As measured by the technique described, serial learning order varies as a function of the learner's extended practice. With continued practice in the learning of serial, nonsense syllable materials, the learner learns more and more extensively from the anterior end of the series; the primacy effect becomes increasingly prominent. A guess is hazarded that this phenomenon is dependent upon the extent to which the learner employs supplementary, symbolic acts in his learning technique.

CHAPTER VI

SERIAL LEARNING ORDER AS A FUNCTION OF AGE

I. Introduction

To speak of learning order as a function of age is most ambiguous. However, there seems to be no alternative because the true variable factors effective in the experiment to be reported have not been identified.

In the preceding chapter it has been suggested that the increasing primacy effect resulting from continued practice may depend upon the subject's increasing use of supplementary symbolic acts in his learning technique. The author wishes to suggest here that the difference noted between earlier and later learning order is at least superficially and qualitatively similar to the frequently observed difference between human subjects and lower animals as regards serial learning order. Expressed in terms of the elimination of errors, it has been shown that the rat learns predominantly from the goal end of a series of acts toward the anterior end; and, contrasted with this, it has been demonstrated that the human subject learns characteristically from the two extremes of the series toward the middle. The study made by Husband (16), in which he compared human adults and white rats in maze learning, clearly shows this difference. In spite of a certain amount of diversity in experimental outcomes, this difference has been quite consistent in its appearance. There is little if any doubt that the human subject makes more extensive use of symbolic supplementation in his learning technique than does the lower animal. The inference, then, is that the observed difference between human and lower animals as regards serial learning order is dependent, at least partially, upon the same factors as that difference between earlier and later learning order for human subjects reported in the preceding chapter. This

rather plausible series of conjectures led to the planning of Experiment IV, reported in this chapter.

Leaving out of account the suggested specific factor of symbolic supplementation, one might reason that if serial learning order is a function of phylogenetic status it may be also a function of ontogenetic status. The following experiment was designed to test this conjecture.

II. The Experiment

(Experiment IV)

a. *The objective.* This experiment was designed to test the conjecture ventured at the close of the preceding section; in general terms, to measure serial learning order as a function of the age or ontogenetic status of human subjects.

b. *The learning materials.* The ten-unit nonsense syllable lists used in this experiment were formulated in a manner similar to that employed in the construction of those used in the preceding experiments.

c. *The subjects.* With the Kuhlmann-Anderson Group Intelligence Test, ten inferior boys were selected from the seventh grade of a public school. By means of the same test, ten superior boys were selected from the eleventh grade of the same school. This technique was used in an attempt to secure groups as widely separated in ontogenetic status as possible. There were irrelevant reasons for selecting from these two particular grades. The mean mental ages for these groups were twelve years and five months, and nineteen years and two months, respectively.

d. *General procedure.* 1. The same apparatus was used as in the preceding experiments.

2. The same instructions were given to these subjects as were given to the adult subjects in Experiment I.

e. *Specific procedure.* 1. Each subject learned a practice list of five syllables before beginning the true experimental program.

2. Each individual in these two groups learned five ten-unit, nonsense syllable series by the anticipation method. A period of two weeks elapsed between the learning of each series and the learning of the following one.

3. In order to control possible differences in the learning materials, two subjects within each group of ten subjects learned the five lists in a 1, 2, 3, 4, 5 sequence; two subjects learned them in a 2, 3, 4, 5, 1 sequence two in a 3, 4, 5, 1, 2 sequence; two in a 4, 5, 1, 2, 3 sequence; and, lastly, two subjects learned the five lists in a 5, 1, 2, 3, 4 sequence.

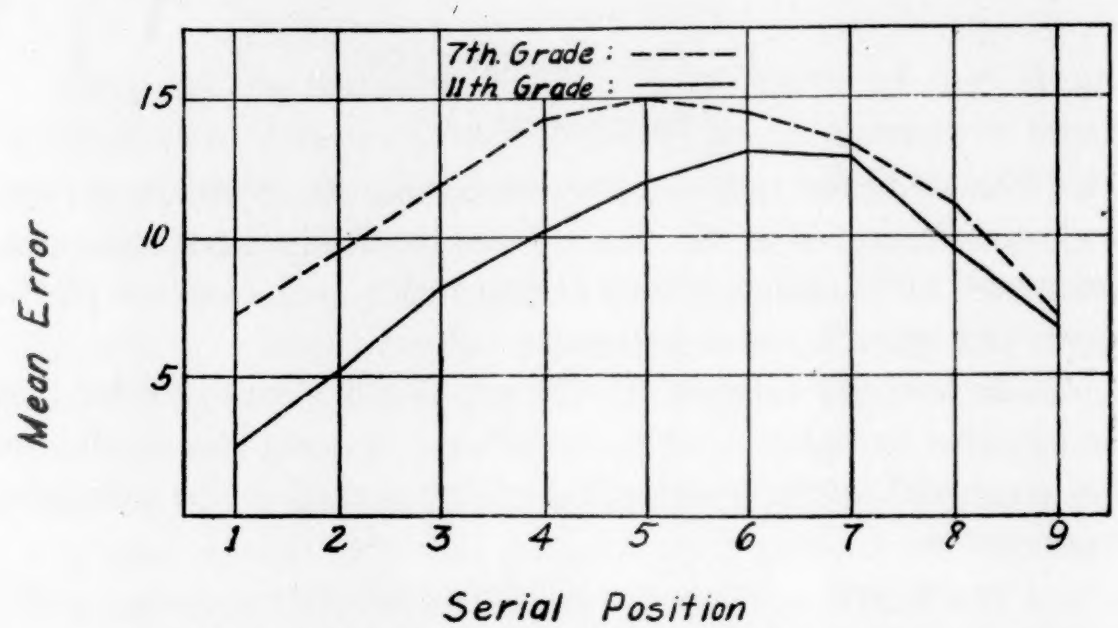

FIG. 14. Serial learning order as a function of age.

4. A complete trial by trial record of all reactions was kept for each learning performance.

III. Explanation of Tables and Figures

The data presented in Table VII were obtained according to the above procedure. From these data the graphs appearing in Fig. 14 were plotted. Each point on these graphs represents the mean of fifty measurements. Each point represents the mean error score for the serial position and for the type of subject indicated.

Table VIII represents a reconsideration of the data from Experiment IV. Specifically, this table represents a simplified comparison of the composite learning order for the first two series learned with the learning order for the last two series

TABLE VII

SERIAL LEARNING ORDER AS A FUNCTION OF AGE. COMPOSITE LEARNING ORDER IS EXPRESSED IN TERMS OF THE MEAN NUMBER OF ERRORS AT EACH SERIAL POSITION. N = 10 (School Subjects)

Group	Serial Position									Mean Total	Comparison				
	1	2	3	4	5	6	7	8	9		Mean Per cent of the Total Errors in the Anterior Half of the Series	Standard Error of the Mean	Mean Diff. (7th Grade minus 11th Grade)	Standard Error of the Mean	Critical Ratio
Seventh Grade	7.3	9.5	11.9	14.2	15.0	14.5	13.4	11.2	7.2	104.2	46.4	1.60			
Eleventh Grade	2.5	5.2	8.1	10.2	12.0	13.1	12.9	9.6	6.8	80.4	34.8	1.73	11.6	2.36	4.92

learned, the data from the two age groups being considered separately.

IV. Results and Interpretations

Referring to Table VII and to Fig. 14, note that the table and the graph indicate that the seventh grade boys found the fifth unit most difficult, while the eleventh grade group found the sixth unit most difficult. When the learning orders of the two groups were compared by computing the mean percentage of the total errors in the anterior halves of the series learned by each group it was found that the eleventh grade group made 34.8 per cent of their

TABLE VIII

Serial Learning Order as a Function of Practice. A Comparison Based upon the Percentage of the Total Errors Made in the Anterior Half of the Series. N = 10 (School Subjects)

Group	Series	Mean Per cent of the Total Errors in the Anterior Half of the Series	Standard Error of the Mean	Mean Diff. (First Two minus Last Two)	Standard Error of the Mean Diff.	Critical Ratio
Seventh Grade	First Two Learned	44.1	2.13			
	Last Two Learned	39.9	2.98	4.2	3.04	1.38
Eleventh Grade	First Two Learned	44.0	2.33			
	Last Two Learned	33.6	2.54	10.4	3.04	3.42

errors in the anterior halves of the series, while the seventh grade group made 46.4 per cent of their errors in the anterior halves. The critical ratio between this 11.6 per cent difference and its standard error of 2.36 is found to be 4.92. Thus, there is reliable evidence that serial learning order, as measured by this technique, varies with the age of the learner.

An inspection of Table VIII reveals some confirmation of the results of Experiment III in Chapter V, wherein it was shown that the primacy effect increased as a function of the extended practice of the learner. The seventh grade boys made 44.1 per cent of their errors in the anterior halves of the first two series learned as compared with 39.9 per cent made in the anterior halves of the last two series learned. The ratio of this 4.2 per cent difference to its standard error is rather small, being 1.38. Therefore, this result is confirmatory only in the sense that there

is a difference in the same direction. The eleventh grade boys made 44.0 per cent of their errors in the anterior halves of the first two series learned and 33.6 per cent of their errors in the anterior halves of the last two series. The ratio of this 10.4 per cent difference to its standard error is 3.42. Thus, there is a highly reliable confirmation of the conclusion in Chapter V, which states that the primacy effect increases with the extent of practice of the learner.

V. Summary

The data examined in this chapter offer some justification of the conjecture submitted at the close of the chapter's introduction. Serial learning order appears to be in some way a function of the age or ontogenetic status of the learner. A group of seventh grade subjects exhibits the primacy effect in serial learning order to a lesser degree than does a group of eleventh grade subjects.

Both groups of subjects studied in the present experiment exhibit a changing learning order, characterized by an increase in the primacy effect, as a function of the extent of practice.

This result agrees with the outcome of Experiment III in Chapter V. Again a guess is hazarded that these phenomena are causally related to the extent to which the learner employs supplementary, symbolic acts in his learning technique. Neither here nor in the preceding chapter is there any reliable assurance that the independent variables effective in the phenomena described have been precisely identified. The isolation of these variables waits upon more extensive investigation. However, it remains conclusive that the gross factors of age and practice must be taken into account in the future study of serial learning order.

CHAPTER VII

RECAPITULATION AND CONCLUSION

This writing began with the simple assumption that remote excitatory tendencies have the dual nature of trace conditioned reactions. In other words, it was assumed that remote excitatory tendencies are characterized by (1) an excitatory phase and (2) an inhibitory delay phase. This major assumption suggested a host of feasible tests of its validity and directed the planning of the two major experiments, I and II. The results of these experiments may be interpreted as supporting this assumption. Further, the hypothesis appears to be of some service in the interpretation of certain of the phenomena of serial learning previously observed.

The two minor experiments, III and IV, were suggested by incidental observations made during the progress of the major experiments.

A detailed review would be unnecessarily repetitious. Each preceding chapter includes its own summary reporting both results and interpretations. For the benefit of the cursory reader the experimental outcomes are repeated here, but without interpretations.

1. As measured by a modified Ebbinghausian technique, remote excitation appears to be a complex function of the length of the forgetting interval. The function, as measured, exhibits an initial increase followed by a decrease.

2. Measured by the same technique, remote excitation appears to be a complex function of the degree of original learning. Overlearning the original materials appears to render remote excitation less measurable, when the interval of forgetting is held constant.

3. There appears a marked discrepancy between the results

referred to in (1) and (2) and the results of previous studies of remote excitation. In neither of these experiments was there any substantial saving in the learning of derived series.

4. Associative inhibition in both test and control lists is shown to vary with the length of the forgetting interval. In these experiments, associative inhibition exhibits an initial increase, followed by a decrease in the course of forgetting. The initial increase is most marked in the control lists.

5. Associative inhibition in the derived control lists appears to vary inversely with the degree of original learning. There occurred a significant reduction in associative inhibition with the greater degree of original learning. No significant change of this sort was observed in the case of derived test lists.

6. Serial learning order is demonstrated to vary with the age of the learner. Older subjects learn more extensively from the anterior end of the series. The primacy effect is less prominent in the learning order of the younger subjects.

7. Serial learning order is demonstrated to vary with the extended practice of the learner. The later lists learned exhibit the primacy effect to a greater extent than do those lists learned earlier in the experience of the subject.

These phenomena are all interpreted in the light of the hypotheses and conjectures under consideration. Insofar as these and other phenomena of serial learning may be deduced from the assumptions of the hypotheses, they may be considered as confirmatory.

The author is fully aware of the loose articulations, at certain points, in the logic of this treatment. At the present preliminary stages in the evolution of this line of thought, this falling short of the clear-cut ideal may be attributed to the complexity of the phenomena involved and to certain lacunae in the experimental evidence.

Considering the interpretations submitted in the various chapters, the only assurance that the fundamental, independent variables have been identified is that indirect assurance afforded by some degree of internal consistency among the observations

which are related according to the hypotheses. These hypotheses are submitted as *working hypotheses,* for criticism and for further experimental testing. Whether or not they prove sound, they serve as fruitful sources of new questions, new experiments, possibly of new discoveries.

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